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MEMOIRS OF THE GEOLOGICAL SURVEY

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THE GEOLOGY OF NORTH WALES,

BY

A. C. RAMSAY, LL.D., F.R.S.,

DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY OF THE UNITED KINGDOM AND MUSEUM OF PRACTICAL GEOLOGY.

WITH AN APPENDIX ON THE FOSSILS,

BY

J. W. SALTER, A.L.S., F.G.S.

REVISED AND ADDED TO BY ROBERT ETHERIDGE, F.R.S.,

PALÆONTOLOGIST TO THE SURVEY.

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NOTICE TO THE FIRST EDITION.

THE Memoir upon the Geological Structure of North Wales which is now published is, I consider, the most important work which has been issued by the Geological Survey during the ten years that have elapsed since I became Director.

Without this work our acquaintance with the details of the classification of the Lower Palæozoic Rocks would have been incomplete. As the author of the Silurian system, I beg further to express my sincere admiration of those successful labours by which Professor Ramsay and his associates carried out, over a very rugged, mountainous, and complicated region, the clearest proofs of the many great folds and dislocations which the Silurian strata have undergone, as well as for the great ability displayed in the delineation of all the various rocks of igneous origin.

By these researches the relative ages of the great dislocations were fixed.

The maps and sections of North Wales, in the preparation of which the labours of Ramsay, Jukes, Aveline, and Selwyn were united with those of my eminent predecessor, Sir Henry De le Beche, have now not only obtained a full description, but all the characteristic fossils, from the very lowest of the Silurian strata or the base of the Lingula Flags, are clearly described by our late Palæontologist, Mr. Salter.

I have, therefore, no doubt that this publication will give satisfaction to foreign as well as native geologists.

RODERICK I. MURCHISON,
Director-General.

Geological Survey Office,
1866.

PREFACE.

THE plan of the book is to give, first, a general sketch of the Geology of Wales, and then such a detailed description of the Silurian rocks of North Wales, that any one may ascertain the structure of any minor area in which he may be interested. An index-map and many sections and diagrams accompany the Memoir, but the special knowledge sought to be communicated can only be mastered in some cases by reference to the larger maps of the Geological Survey, published in sheets, on a scale of one inch to a mile, and to the sections, on a scale of six inches to a mile, which illustrate the maps. Nevertheless, for general purposes, the main geological features of North Wales may be understood by help of the index-map, sections, and diagrams that accompany this Memoir; and, indeed, by merely reading those parts that are printed in large type all the chief facts connected with the subject may be made out. It is evident that such a book would be incomplete without an Appendix on the Fossils, which was, for the first edition, prepared by Mr. Salter, and has now been corrected and extended by Mr. Etheridge, with that accurate knowledge of Silurian forms for which both have been distinguished.

A few words of explanation may here be given with regard to the sense in which the word *greenstone* is used in this book. It embraces several varieties of rocks in which triclinic felspar forms an ingredient associated with hornblende or augite, and which as originally solidified afterwards sometimes underwent changes both physical and chemical, as, for example, the change from augite into hornblende. Those associated with the Lower Silurian volcanic lavas and ashes have this in common, that all of them are intrusive, and also that their intrusion ranged through various periods of time that extended from the formation of the Arenig rocks to the close of the deposition of the Bala limestone.

Of the numerous minor dykes of the counties of Merioneth, Caernarvon, and Anglesey, most of which have a north-western strike, some of them are certainly post-carboniferous, and possibly the whole may belong to the same general period.

Though such a work as this has nothing of a popular character in it, and makes somewhat dry reading, yet it is likely not to be without use to those who, led by business or scientific pursuits, may feel it necessary to master the geological structure of North Wales.

ANDREW C. RAMSAY,
Director-General.

Museum of Practical Geology
and Geological Survey Office,
Jermyn Street, London,
1881.

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THE GEOLOGY OF NORTH WALES.

CHAPTER I.

Nomenclature of the Cambrian and Silurian Series.

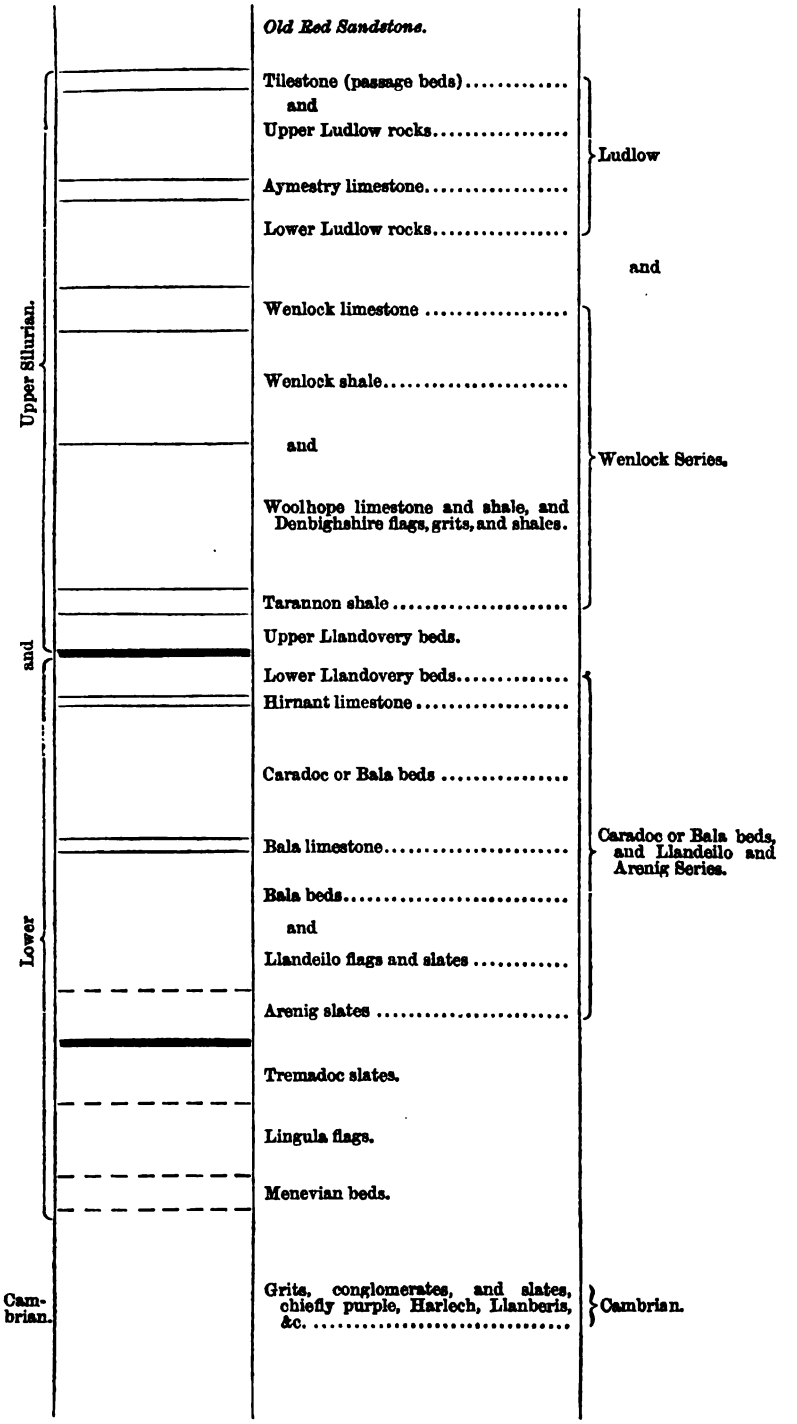
The following column, showing the order of succession of the Silurian and Cambrian strata of England and Wales, is in its great, and in most of its smaller, divisions identical with those published in 1839 by Sir Roderick Murchison in the Silurian System. The chief differences consist in additions to our knowledge due either to the discovery since that period of new and subordinate divisions, or to the better understanding of the precise stratigraphical relations of members of the whole series.

With the exception of the Arenig, Tremadoc, and Menevian beds, the divisions indicated in the column were all sanctioned by the late Sir Henry de la Beche during the progress of the survey; and all the modifications, with these exceptions, were also in some form recognized by the late Sir Roderick Murchison in the last edition of "Siluria."

The thin dividing lines indicate that there is no marked stratigraphical break between the formations, and the thicker lines are intended to indicate the relative importance of the palæontological and stratigraphical breaks (unconformity) between the different members of the series. Where a dotted line occurs it implies that no geological line of division for these formations has been drawn on the maps. For lithological reasons that will appear further on, it never occurred to any one while the Survey of Wales was in progress to attempt to separate the Lingula and Tremadoc beds from each other, or from the overlying Llandeilo and Bala beds; but with increased knowledge and experience it might possibly now be done.

In no single area is the series quite complete; and in the form in which it stands in the column, it has been built up from several districts and by several hands.

COLUMN SHOWING THE SUCCESSION OF CAMBRIAN AND SILURIAN STRATA.



I shall now endeavour to give a brief history of the discovery of the different members of the series, the names that were given them, and the progress of those observations that extended over more than 20 years, and resulted at length in establishing their stratigraphical relations to each other. Each geologist in turn found it needful to modify his original views more or less, partly from the occasional excessive difficulty of understanding the arrangement of the rocks of some special district, partly from the local absence of one or more members of the series, without any visible unconformity to suggest it. Differences of opinion still exist, but chiefly respecting names and classification, and though these may be interesting to individuals, as I understand them, they neither affect the order of stratification nor the palæontological facts, both of which can be readily understood by whatever names the strata are called. Minor points will continue to be discussed as long as new fossils and new fossiliferous areas continue to be discovered. In Wales, as long as it is possible to refine in geological mapping, especially on the broad hills of Caermarthenshire and Cardiganshire, improvements in detail may be made, and it may be possible to divide the strata of that area into Lower Llandovery and Caradoc or Bala beds.

The following paragraphs contain a condensed account of the origin of the names of the formations and sub-formations used in this memoir.

The micaceous sandstone called TILESTONE in Caermarthenshire and Breconshire was described by Sir Roderick Murchison in a paper communicated to the Geological Society in 1833 (Proc. Geol. Soc., vol. i., p. 473), and afterwards in the "Silurian System," published in 1839. It was then considered as forming the base of the Old Red Sandstone. In 1842 it was mapped by Mr. T. E. James, under the superintendence of Professor Phillips, and referred by the latter and Sir Henry de la Beche to the top of the Ludlow rocks, with which its numerous fossils unite it. It has been allowed to remain there, though in Herefordshire and Shropshire there are symptoms of strata occupying the same position passing gradually into the Old Red Sandstone.

The LUDLOW ROCKS, the AYMESTRY LIMESTONE, and the WENLOCK LIMESTONE and SHALE were partly described in Shropshire and Herefordshire by Sir Roderick Murchison in the Memoir of 1833; and subsequently elaborated in the "Silurian System." The position assigned to these formations and the names then given them, have been universally accepted in British geology, and their equivalents have been described in many other regions. They were named from these places where the best typical sections of these strata may be seen.

The WOOLHOPE LIMESTONE and SHALE were, when the Silurian System was published (1839), identified with the *Hollies limestone*, and called the *Caradoc* or *Woolhope limestone and shale*. The Hollies and the Woolhope limestones have, however, since been proved to be on different horizons; and the latter, being simply a subordinate part of the Wenlock series, was included in

it by Sir Henry de la Beche and Professor Phillips in 1843, and published in that form shortly after in the maps and sections of the Geological Survey, and also in Professor Phillips' work on "The Malvern Hills," &c., published in 1848 in the "Memoirs of the Geological Survey of Great Britain," and this view Sir Roderick Murchison also adopted.

The DENBIGHSHIRE SANDSTONES were first described by Mr. Bowman, in 1841, as "coarse slates and flags with large Orthocera," and included by him as a subordinate part of the Upper Silurian rocks.* In 1842 Mr. Daniel Sharpe noticed these grits at Mallwyd, and described them as part of the Wenlock series.† They were afterwards, in 1843, described by Professor Sedgwick,‡ and correctly stated to form a base to the Denbighshire flagstones, which he identified with the Upper Silurian rocks, their lower part being therefore the equivalent of the Wenlock shale.

In 1845 these strata first began to be mapped by the Geological Survey, and lying beneath the commonly recognised Wenlock shale, they were for a time erroneously believed to be the western representatives of the Caradoc Sandstone of Shropshire and of the "Pentamerus beds," then classed by every one as part of that series. This error was shortly afterwards corrected.

The TARANNON SHALES underlie the Denbighshire Sandstones, and by the Geological Survey were first considered to form the uppermost part of the Bala beds, but when the maps were nearly completed, Mr. Aveline began to suspect that they belonged rather to the Denbighshire Sandstone series, a suspicion entertained by Mr. Jukes before; and I believe at a much earlier date Professor Sedgwick had mentioned them as pale-coloured earthy slates or "paste rock." In 1855 I considered it necessary to define precisely the base of the Wenlock shale in the western parts of South Wales, a work that no one had previously accurately accomplished; and in accordance with the instructions of Sir Henry de la Beche, Mr. Aveline commenced the work. During its progress he detected the "pale" or Tarannon shales overlying the Upper Pentamerus or Llandovery beds near Builth; and as in North Wales they underlie the Denbighshire Sandstones, it became evident that these shales are on a higher horizon than the Llandovery or Pentamerus beds of Shropshire, which are the equivalents of those of Builth. The fossils contained in the Tarannon Shale are essentially the same as those of the Wenlock Shale.

The UPPER LLANDOVERY BEDS, first called Pentamerus beds and Hollies limestone (= the MAY HILL SANDSTONE) were originally considered by Sir Roderick, then Mr. Murchison, as the highest beds of the Caradoc Sandstone, and conformable with it. In the first editions of the Maps and Sections the Geological Survey taking this view, overlooked the special importance of these rocks in the country between Wenlock edge and Caer

* Reports, British Association, 1841.
† Proc. Geol. Soc., vol. iv., p. 12. ‡ Proc. Geol. Soc., vol. iv., p. 18.

Caradoc, and the strip of Pentamerus limestone and conglomerate that laps round the Longmynds and the overlying Llandeilo flags, was considered as part of the true Caradoc Sandstone. The May Hill rocks were also thought to form part of that formation. In the Geological Journal for 1852, Professor Sedgwick and Mr. McCoy partly corrected these errors by showing that the fossils of the May Hill series were, to a great extent, distinct from those of the Caradoc Sandstone, and that they possessed more of an Upper than of a Lower Silurian character. Profiting by this hint, the Geological Survey re-examined the Shropshire rocks, and it was found by Mr. Aveline, and corroborated by myself, that the Upper Pentamerus beds lie *quite unconformably* on the true Caradoc Sandstone, while Mr. Salter showed that the latter is by its fossils the precise equivalent of the Bala beds of North Wales. The fossils of these Pentamerus beds were also found to agree with those of the May Hill Sandstone, and the equivalents of the Tarannon shale were found to overlie them in Shropshire. The whole seemed to pass nearly conformably under the Wenlock shale. In 1854 Professor Sedgwick corroborated these views.* Physically the break between the Upper Llandovery beds and the strata below may be inferred to be complete. In Shropshire and at Builth the unconformity is visible, and in the Malvern area the Upper Llandovery beds, lie on Upper Lingula flags with *Dictyonema*. The Upper Llandovery beds on the banks of the Onny lie on the higher part of the Caradoc Sandstone (= Bala beds), and as they strike northward, gradually overlap the higher strata, till, on the banks of the Severn, near Buildwas Abbey, they rest on the lower beds of the same formation. A few miles from Wenlock Edge they lie on the nearly vertical edges of the Cambrian or Longmynd rocks, and between Church Stretton and Chirbury, on all the strata between the Lingula and Caradoc beds. In South Wales, between Builth and Newbridge, they lie equally unconformably on the Llandeilo flags, but 14 miles off at Noeth Grug they rest on the Lower Llandovery beds, which are higher than any part of the Caradoc Sandstone of Shropshire; but again they rapidly creep across these to the south-west, and in the river Sawdde the Upper Llandovery beds lie directly on the Llandeilo flags. There is no unconformity so complete as this yet observed in other members of the British Silurian strata from the Llandeilo flags upward.

The LOWER LLANDOVERY BEDS at Noeth Grug, near Llandovery, underlie the Upper Llandovery formation. In mineral character they so strongly resemble each other that up to 1856 no geologist distinguished between them, and when in that year it was found that in neighbouring districts only the uppermost o the Noeth Grug beds existed (Upper Llandovery or Pentamerus beds), it was then clearly necessary to attempt the task of separation. While engaged on this work Mr. Aveline found it lithologically, a work of considerable difficulty. Nevertheless this

* Philosophical Mag. for Oct. and Nov.

difficulty soon ceased in consequence of the rapid overlap of the Lower by the Upper Llandovery beds, so that the apparent local conformity is probably accidental.

The CARADOC SANDSTONE was first noticed by Sir Roderick Murchison in the Proceedings of the Geological Society in 1833, and in 1834 these rocks were described by him under the name of Horderley and May Hill Sandstone. Subsequently, in the SILURIAN SYSTEM (1839), these strata were called Caradoc Sandstone from the circumstance of their being typically developed in the neighbourhood of Caer Caradoc. The lists and plates of fossils included as part of this series those of the Pentamerus beds. This error he subsequently corrected.

In 1838 certain rocks were described by Professor Sedgwick in the Proceedings of the Geological Society, under the name of Bala beds, forming the upper part of his Cambrian series. They were then supposed to lie below the recognized Silurian rocks, though some of their fossils were known to be the same. In 1840 Mr. Bowman recognized their Silurian character from the fossils, and remarked that if there be a boundary between Silurian and Bala beds, it must be defined by other than fossil evidence. In 1842 Mr. Daniel Sharpe also concluded correctly from fossils that they were the equivalents of the Lower Silurian rocks generally,* while in 1845 and 1846 the Geological Survey proved that they formed part of a series of rocks that in South Wales had been admitted as members of the Silurian series since 1842. In his anniversary address, as President of the Geological Society, in the year 1842, Sir Roderick Murchison also stated that "the "term Cambrian must cease to be used in zoological classifica- "tion," with respect to the Bala beds of North Wales, &c., and that "the conventional line which has been set up in the map of "the Silurian region, between the Lower Silurian and the Cam- "brian rocks, has no longer any reference to strata identified by "distinguishing organic remains, for the same fossils are found "in strata on each side of that demarcation."† In 1853 Mr. Salter examined the fossils of the district on the ground, and determined that they were generally identical with those of the Caradoc Sandstone. Caradoc Sandstone and Bala beds are, therefore, equivalent terms, the former ever since the publication of the "Silurian System" in 1839 having been used to express the higher part of the Lower Silurian series, while in 1838 the name of Bala beds for equivalent strata was used by Professor Sedgwick to express the higher part of his Cambrian rocks, at that time, and for several years after, generally believed to be older than any formation of Silurian age.

The LLANDEILO FLAGS were first named *Trilobite Schists* by Sir Roderick Murchison in 1834 in his descriptions of the Shelve country, the Carneddau, near Builth, and of the neighbourhood of Llandeilo, and under this name, near Shelve, were included the strata as low as the base of the Stiper stones, the whole of these

* Proc. Geol. Soc., vol. iv., p. 10. † Proc. Geol. Soc., vol. iii, p. 642.

rocks being older than the Caradoc Sandstone. After 1848 the Officers of the Geological Survey were in the habit of considering the slates close below and above the Arans and Arenigs, &c. of North Wales, as equivalent to the Llandeilo flags of Builth and Shelve.

It was, however, somewhat later (1853) shown by M. Salter and Professor Sedgwick, that these strata in the district of the Arans and Arenigs are of earlier date than the original Llandeilo flags of Llandeilo, and are in fact, according to the evidence afforded by fossils, the equivalents of only the lower part of the great series of rocks that lie between the Stiper Stones and Chirbury, or roughly speaking of that part of the Lower Silurian strata, that lies east of the turnpike road at the western base of Shelve Hill. The whole of the series from the Stiper Stones towards Chirbury had been previously named by Murchison Llandeilo flags, but afterwards from Shelve Hill eastward, he called the strata as far as the Stiper Stones "Lower Llandeilo flags," or in more modern nomenclature the Arenig beds. Possibly, however, the lowest part of the strata overlying the Stiper Stones may belong to the Tremadoc States.

At the time of the publication of the "Silurian System," and for several years after, it was generally believed that all the rocks of South Wales in Cardiganshire, North Pembrokeshire, and other districts were of older date than the Llandeilo flags, and they were therefore assumed to be part of the Cambrian System of Professor Sedgwick. In 1842 I discovered that the Silurian beds on the banks of the Towey in Caermarthenshire were repeated further north in numerous undulations. I informed Sir Henry de la Beche, who at the same time confirmed the facts by a series of independent observations. Shortly after, in the same year, I found *Pentamerus* (*Stricklandinia*) *lens*, and other Lower Silurian fossils in certain bands of grit and conglomerate near Dolaucothy, and this first led to the strata between the Towey and Cardigan Bay being thrown into the Silurian series.

The Arenig Beds have already been alluded to in the foregoing paragraphs on the Llandeilo flags. They first received their name from Professor Sedgwick in 1843, who considered them the equivalent of the Skiddaw Slates. Where the sections are complete, as at St. David's and in part of Shropshire, they lie between the ordinary Llandeilo flags and the Tremadoc Slates, and were included by Murchison in his work called Siluria, as part of the Llandeilo series under the name of Lower Llandeilo flags. In 1874 I traced the base of this formation from Criccieth to Tai-hirion, and also partly south of the estuary of the Mawddach, and in 1875 Mr. Ward and Mr. Hebert completed the work in Merionethshire. No one has attempted accurately to define its upper boundary in North Wales, and it seems to me that it passes gradually and conformably into the superior slaty series.

Tremadoc Slate.—These strata were long ago (1846) described by Professor Sedgwick on special lithological grounds,

but it was not till after 1857 that Mr. Salter determined by their suite of fossils that they deserve to be ranked as a distinct sub-formation, few of the forms occurring either in the Lingula flags below or the Arenig Slates and Llandeilo flags above.

The LINGULA FLAGS were first named in consequence of Mr. Davis's discovery of Lingula Davisii in these rocks near Tremadoc, in 1845, for this fossil was soon found to be so characteristic, that it gave a name to the strata. They have not heretofore been specially mapped in North Wales by a line dividing them from the overlying Tremadoc Slates, and it appears certain that they lie conformably one to the other.

The MENEVIAN BEDS were first distinguished at St. David's by Messrs. Salter and Hicks, as holding a suite of fossils which are mostly distinct from those in the overlying Lingula flags. They were named Menevian in reference to the ancient Roman name of the district. In North Wales they are probably never more and often less than a hundred feet thick, and while they pass conformably under the Lingula flags, they pass equally conformably and by gradation into the underlying Cambrian Grits.

The CAMBRIAN ROCKS (purple grits, slates, &c.) of the Longmynd were in "The Silurian System," shown by Sir Roderick Murchison to underlie the whole of his Silurian strata. When in 1846 and 1848 the Geological Survey mapped the equivalent rocks in Merionethshire and Caernarvonshire, they naturally adopted this name for these deposits. Stratigraphically they occupy the same position, and lithologically they much resemble each other.

COLOURING OF THE MAPS.—In 1841 the Geological Survey began to map the Silurian rocks at Haverfordwest in Pembrokeshire, and Sir Henry de la Beche was unable in that neighbourhood to detect any base for the Silurian strata. In the same year at St. David's I traced a provisional line between the black and the purple slates, and this was afterwards adopted as the line between the Silurian and Cambrian strata. In 1841 Sir Henry de la Beche also discovered graptolites in the black slaty rocks of Fishguard near the fort, and about the same time Mr. Aveline found traces of fossils at Dinas Head on the same coast. Previous to this time Mr. Henry McLauchlan had found *Calymene duplicata* at Abereiddy Bay and other fossils elsewhere between Fishguard and St. David's Head, and soon after I found *Didymograpsus Murchisoniæ, Lingula Ramsayi,* and *Bellerophon perturbatus* at the same slate quarries. Graptolites were also found by Sir Henry de la Beche near Cardigan, and in the spring of 1842 fragments of Silurian fossils were found by me near Newcastle Emlyn. I also found encrinites several miles north of Caermarthen. The strata of all of these areas were, however, up to these dates generally presumed to be older than the Landeilo flags of Sir R. Murchison, although these discoveries inclined Sir Henry de la Beche to believe that they might turn out to be of Lower Silurian age.

In June 1842, while working at Llandeilo, I discovered in so-called Cambrian ground, in a brook near Llwyd-coed-uchaf, shales and thin impure limestones and grits, dipping north, and full of Lower Silurian fossils. I concluded that they were Lower Silurian rocks rolled over to the north, and supposed them to form a part of the series higher than the trilobitic Landeilo flags of Dynevor Park. A more recent analysis of the fossils by Mr. Salter showed, in fact, that they are Bala or Caradoc beds, and this agrees with the position I assigned them. I immediately informed Sir Henry de la Beche of the circumstance, and a single day later he detected similar appearances near Llangadoc. In August of the same year I found *Stricklandinia* (*Pentamerus*) *lens* at Melin-newydd, near Pumpsant, and roughly identified the strata with the well known Pentamerus beds of Noeth Grug, which at that time were not known to be divisible into Upper and Lower, and were in fact considered to belong to the Caradoc Sandstone. Pursuing these investigations the whole of South Wales as far as Cardigan Bay was shown to be simply a repetition of Lower Silurian strata, prolonged in numerous undulations, and it was therefore (no one for years objecting) coloured Lower Silurian. We believed, however, as we proceeded northward that we might at length reach a lower set of fossiliferous Cambrian rocks, but found instead the recognized Lower Silurian strata, striking directly into the Bala country. Hence the greater portion of Wales, under the name of Llandeilo, Bala, Tremadoc and Lingula beds, came to be coloured Lower Silurian by the Geological survey; and it was not till we reached the nearly barren purple and green grits and slates of Merionethshire below the Lingula flags, that we mapped (as Cambrian) any formation distinct from the great fossiliferous Lower Silurian series.

CHAPTER II.

Geographical Arrangement and Physical Relations of the Palæozoic Rocks of Wales and Shropshire.

The following Memoir relates chiefly to the rocks of Merionethshire, Caernarvonshire, Anglesey, and part of Denbighshire, but before proceeding to detailed description of this area, I shall attempt to give an idea of the general geographical disposition of the Silurian and Cambrian rocks of Wales and its neighbourhood, and of their local relations to those later members of the Palæozoic series that chance to bound them.

The oldest rocks in Wales and Shropshire rise to the surface in six districts:—

First, Anglesey, the greater portion of which consists of mica and chlorite schists, gneissic rocks, grits, and quartz-rock, all considered to be of Cambrian age.

Second, the Bangor and Llanberis district, comprising the altered purple, green, and chloritic, slaty, arenaceous, and con-

glomeratic beds west and south-west of Bangor; together with the purple and green slates, and grits on the banks of the Ogwen around Bethesda, the lakes of Llanberis, Llyniau Nant-y-llef, and Llanllyfni.

Third, the Lleyn district, consisting of the ancient schists on the south side of Caernarvon Bay, including Bardsey Island and the coast from Bardsey Sound to Porth dinlleyn and Porth Nevin.

Fourth, the Harlech district, an oval-shaped tract, occupying most of the ground between the Barmouth estuary and that of Traeth-bach, and principally composed of greenish grits, occasionally interstratified with purple and green slates.

Fifth, the district of St. David's, comprising the purple sandstones, grits, and slates, and certain grey and blue slates on the north side of St. Bride's Bay, in Pembrokeshire.

And sixth, the purple and green grits, conglomerates, and slaty beds of the Longmynd, and the neighbourhood of Shrewsbury.

The term *Cambrian* is restricted in this Memoir to the rocks mentioned above, which, through the researches of Mr. Hicks at St. David's, have only since 1863 been known to contain a considerable fauna. In other areas only annelide burrows and a few trilobites have yet been found. The strata that lie between them and the Old Red Sandstone are called *Silurian*, on the ground that in Shropshire and in part of South Wales they were so originally termed by Sir Roderick Murchison.* This name was subsequently extended over Wales by the Geological Survey to areas previously considered older, but found to be of identical date. Although there are great generic and specific differences in the fossils of some of these Silurian formations, trilobita, cystideæ, certain genera of cephalopoda, pteropoda, and distinctive brachiopoda, &c. are found throughout, and Graptolites more or less everywhere, except in the Menevian, Lingula flags, and Tremadoc beds.

1. *Anglesey.*—In Anglesey the Cambrian rocks are overlaid by Arenig slates on which rest later Lower Silurian shales and grits, which principally lie in the central part of the island, north, north-east, and south-west of Llanerchymedd. The Old Red Sandstone and Carboniferous Limestone rest on them unconformably in a broad strip between Dulas Bay, Red Wharf Bay, and Malldraeth Sands. A succession of faults that follow a straight course from Red Wharf Bay to Llanddwyn Island, throw the Carboniferous Limestone and Permian rocks against the Cambrian schists that occupy the south-east quarter of the island. A patch of Silurian rocks overlaid by Carboniferous Limestone rests on these schists between Llanfihangel, Puffin Island, and Beaumaris, and the same limestone, with occasional beds of sandstone, bounds the schists on a line between Llanfair-pwll-gwyngyll and Newborough Marsh. A small patch of red unproductive Coal-measures rests on the limestone opposite Caernarvon.

* The rocks beneath the Stiper Stones, which represent the Lingula flags, were however not known under this name originally, but have since been included with them.

2. *Caernarvonshire.*—The Cambrian rocks of part of the north-west of Caernarvonshire belong geographically to the same area as those of Anglesey, being only separated from them by the Menai Straits. In both areas the Carboniferous rocks rest unconformably upon them. A band of unproductive Coal-measures forms a narrow strip of coast line between Caernarvon and Llanfair-is-gaer, and is succeeded by a belt of Carboniferous Limestone from thence to Gored-girth on the coast near Bangor. A fault throws these rocks against a felspathic mass in places almost of a granitic character, that lies between Caernarvon and Bangor, and (except near its northern termination) separates the Carboniferous strata on the Menai from the Silurian and Cambrian rocks of this part of Caernarvonshire. The last-named strata, repeated by a north-east fault, lie in two patches, one between the Lavan Sands and Caernarvon, and another running from the banks of the Ogwen near Bethesda by Llanberis to Llanllyfni, and the sea in Caernarvon Bay.

3. *Lleyn.*—The third Cambrian area, much metamorphosed and often resembling the equivalent rocks in Anglesey, forms a broad belt of land between Bardsey Island and Porth-dinlleyn. It is bounded on the south-east by the Lower Silurian rocks of Lleyn,* through which are protruded numerous large bosses of igneous rocks in the area that lies between Aberdaron, Criccieth, and Yr Eifl or the Rivals.

The Cambrian rocks near Llanberis and Bethesda are overlaid by the Lingula flags (no Menevian beds having yet been recognised in the district), and these are succeeded in ascending order by strata, the higher part of which certainly represents the Bala beds or Caradoc sandstone, while between these and the Lingula flags, Tremadoc Slates, if present at all, have not been certainly identified with those of the Tremadoc area. Magnificent sections of the Caradoc rocks occur in the Passes of Llanberis and Nant Ffrancon, and on the heights of Snowdon, Y Glyderfawr, and Carnedd Llewelyn, and, indeed, in the entire series of slaty rocks, interstratified with igneous products that lie between the Vale of Conwy and Caernarvon Bay.

4. *Merionethshire.*—The fourth Cambrian area is the oval-shaped mass of Merionethshire, between Traethbach and the estuary of the Mawddach, the grits and conglomerates of which are surrounded on the north-east and south by the Menevian and Lingula flags, dotted with occasional igneous protrusions. Above the Lingula flags lie the Tremadoc and Arenig slates, the latter being overlaid by, and apparently associated with, great accumulations of volcanic ashes, principally felspathic, and of felspathic traps or lava flows, extending in a crescent form round the Cambrian, Lingula, and Tremadoc beds, and forming the heights of Cader Idris, and the Arans, Mynydd Nodol, Craigd-du, the Arenigs, the two Manods, and Moelwyn-mawr and Moelwyn-bach. It will

* Lleyn is the Welsh name of the promontory that separates Caernarvon Bay from Cardigan Bay.

be shown that this volcanic series was of much earlier date than that which forms the high mountain tracts in Caernarvonshire, between the upper part of Traeth Mawr, Llanrwst, and Conway. The former lies on the horizon of the Arenig beds or Lower Llandeilo flags of Sir Roderick Murchison, the latter in the middle of the Bala beds or Caradoc sandstone. Till the districts were mapped by the Geological Survey, they had been described by geologists as the same.

Caradoc or Bala Beds.—The typical Bala or Caradoc beds lie in the Bala district between Dinas Mowddwy, Bettws-gwerful-goch, and Bettws-y-Coed. They consist of black and blue slates, and grey and brown arenaceous beds, the Bala limestone, generally very impure, lying about the middle, and averaging from 20 to 30 feet in thickness. Between the limestone and the lower traps of the Arenigs and Llyn Conwy, two and sometimes three thin and imperfect beds of volcanic ashes represent the whole of the vast volcanic accumulations that lie between Dolwyddelan and Conway, and from thence to the south-west by Carnedd Llewelyn, the Glyders, Snowdon, Moel Hebog, and Llwyd Mawr. The middle part of the Bala beds, including the limestone, is most fossiliferous, the slates below, and the slaty and sandy interstratifications above, being comparatively barren.

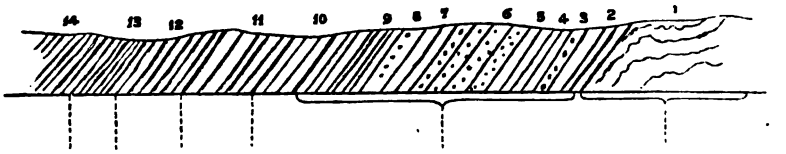
5. *St. David's, Pembrokeshire.*—Eastward of Aran Mowddwy and close below the Tarannon Shale, the uppermost strata of the Bala beds pass into a set of sandy strata, several hundred feet in thickness. These in the almost total absence of distinct fossils, are doubtfully assumed to be equivalent to the Lower Llandovery beds, which, passing southward, become thickened, and range through large portions of the western parts of the counties of Montgomery, Radnor, Brecon, Cardiganshire, and the northern halves of Caermarthenshire and Pembrokeshire. In Pembrokeshire volcanic rocks, resembling those of North Wales, are associated with Arenig and Llandeilo slates, beneath which at Whitesand bay there occurs in descending order the Tremadoc, Lingula, and Menevian Strata, and at the bottom of all, on the north side of St. Bride's Bay and in Ramsey Sound, the fifth Cambrian patch rises to the surface, consisting of purple and red slates, and grey and purple sandstones, conglomerates, and shales, in part lithologically resembling their equivalents in Caernarvonshire.

At St. David's the general succession of strata as published by Messrs. Salter, Hicks, and Harkness* is typified in the following diagram, which merely shows the order of superposition without reference to precise localities, or to the disturbances and faults which affect the rocks of the district. It is enough to mention, that all the strata shown in the diagram are to be found on the coast or not far inland, between Solva on the south, and Abereiddy Bay on the north, and also partly in Ramsey Island. The lithological character of the Cambrian strata south of White-

* For details on this subject, see Journal of the Geological Society, Vols. 21, 1865; 23, 1867; 27, 1871; 28, 1872; and 29, 1873.

sand Bay, as shown in the diagram, is taken from Mr. Hicks' description with a few very slight modifications from personal knowledge.

Fig. 1.



1. Altered rocks.
2. Talcose, schist, and hornstone, sometimes brecciated.
3. Red and purple conglomerate, 60 feet.
4. Greenish-grey micaceous flaggy sandstones, 460 feet.
5. Fine grained red flaggy beds, which contain *Lingulella ferruginea*, *L. primæva*, *Leperditia Cambrensis*, *Discina* sp., 50 feet.
6. Massive purple grits and sandstones with annelide tracks, 1,000 feet.
7. Yellowish grey sandstones, flags, and shales with *Plutonia Sedgwickii*, *Conocoryphe Lyellii*, *Microdiscus sculptus*, *Agnostus Cambrensis*, *Paradoxides Harknessii*, *P. Hicksii*, *Theca* sp., and *Protospongia fenestrata*, 150 feet.
8. Grey, purple, and red flaggy sandstones and slates containing most of the genera and species mentioned above, 1,500 feet.
9. Grey flaggy beds with *Paradoxides Aurora*, *Conocoryphe bufo*, *Theca antiqua*, *Th. penultima*, and *Lingulella ferruginea*.
10. Menevian beds richly fossiliferous, about 700 feet.
11. Lingula flags, 2,500 feet.
12. Tremadoc beds, about 2,000 feet.
13. Arenig slates.
14. Llandeilo slates.

It will be observed that in Nos. 7 and 9 the fossiliferous strata are grey, and that the strata numbered 8 also partly consist of grey sandstones and slates, while in No. 5, which is much less fossiliferous the strata are exclusively red. These discoveries were published by Mr. Hicks in 1871, in Vol. 27 of the Journal of the Geological Society, and threw a new light on the Cambrian strata. The connexion between colour and the presence of fossils in these strata I have elsewhere attempted to explain, and the subject is also noticed in this volume at p. 23.

The fossils in the Menevian, Lingula, and Tremadoc beds do not essentially differ from those found in the same strata in North Wales, and may be referred to in the Appendix by Mr. Etheridge at the end of the volume.

6. *The Longmynd.*—The Cambrian rocks of the sixth area crop out from beneath those equivalents of the Lingula flags that lie immediately east of and under the Stiper Stones, no Menevian beds having as yet been observed in this area. On the south, and partly in the south-east, they are enclosed unconformably by the Upper Llandovery rocks, or Pentamerus sandstones, conglomerates, and limestone (equivalents of the May Hill sandstone), and partly by the Wenlock shale. On the east, about Church Stretton, they are partly bounded by Caradoc rocks and Wenlock shale, thrown against them by faults, and from Le Botwood, north and westward they are enclosed by Coal-measures, overlaid by Permian rocks, and New Red Sandstone. The Lingula, Arenig, and Llandeilo beds, that overlie the Cambrian rocks of

the Longmynd on the west, are encircled by the Pentamerus and Wenlock strata, which rest on them in the same unconformable manner that they do on the Cambrian grits of the Longmynd.

A long strip of Caradoc Sandstone runs from the Wrekin near Coalbrook Dale by Caer Caradoc, for 20 miles to the south-west. It is separated from the Wenlock and Tarannon shale by the same Upper Llandovery beds that underlie the Wenlock series on the flanks of the Cambrian and Lower Silurian rocks of the Longmynd and Shelve, and also west of the Wye near Builth, and in Caermarthenshire north-east and south-west of Llandovery. In all these areas there is a marked unconformity between the Upper Llandovery rocks and the underlying strata of whatever age.

Llandovery Beds and Tarannon Shale.—In North Wales, as already stated, the Upper Llandovery rocks are absent, and the Bala beds, as far north as the ground 6 miles south-east of Bala Lake, are overlaid by a long strip of grits probably belonging to Lower Llandovery strata, and this is overlaid by pale grey, purple, and green Tarannon shales.* These shales (the Upper Llandovery beds being absent) form the lowest part of the Upper Silurian rocks of North Wales, and on the west of and below the Denbighshire grits they run in a narrow and nearly unbroken line from the mouth of the Conwy to Melynllyn near Llanddewi-Ystrad-Enny. At and towards the southern end of this subformation, they lie quite unconformably on the various underlying members of the Lower Silurian strata. On the sides of the boss of the Llandeilo flags of Builth they are absent, but appear in force on the banks of the Wye near Newbridge, resting on Bala beds and Lower Llandovery rocks, and further south towards Garth on Upper Llandovery beds, where they are overlapped by Wenlock shale. They next appear from under the Wenlock shale at Noeth Grug, and strike south-westerly near Llandovery to the neighbourhood of Pen-y-lan, resting on Upper Llandovery beds. Near Pen-y-lan the Tarannon shales are overlapped by the Wenlock shale and they do not again appear in South Wales.

On the north-west flanks of the Berwyn area, the Tarannon shales separate the Denbighshire grits from the Bala beds. On the south they are partly cut off by a fault along the range of Pen-y-bylchau, but again appear in the country near Llanfyllin and Meifod. The same shale runs along the southern flank of the hills of Cyrn-y-brain north of Llangollen, and of another patch of the Bala beds east of Llanelidan.

Denbighshire Grits and Wenlock Shale.—The Denbighshire grits succeed the Tarannon shale, and, interstratified with slaty shales, form the base of the ordinary Wenlock strata. They run from north to south, in a long sinuous and sometimes broad strip, from the mouth of the Conwy to Melenydd, immediately north of Llanddewi-ystrad-enny, in Radnorshire. East of Bala Lake they lie in a trough, from two to four miles wide, and the Tarannon

* For further notice of the Llandovery beds, see p. 17, chap. 30.

shales, and Lower Silurian rocks of the Berwyn hills rise from underneath their eastern boundary. These in general structure resemble those of Bala and Caernarvonshire, but the igneous rocks associated with them are much less largely developed.

North of the Berwyn hills between Llangollen and Corwen the Denbighshire grits, more shaley in character, overlie the Tarannon shales; and in the valley of the Vyrnwy and eastward by Welshpool and the Longmountain, and round the Lower Silurian rocks of the Shelve and Corndon country, this sandy character of the lower part of the Wenlock Shales entirely disappears.

In Radnorshire, 10 or 12 miles north of Builth, the Denbighshire grits die out, but their equivalents in a more shaley form are believed by Mr. Aveline to strike into South Wales. This shaley condition is also characteristic of part of the formation in the typical country near Wenlock Edge, as well as in Caermarthenshire, where in places these strata rest capriciously, sometimes on the Upper Llandovery beds, sometimes on the Caradoc Sandstone or Bala beds, and near Builth and west of Llanarthney on the Llandeilo flags.

Between the mouth of the Conwy and Corwen the Denbighshire grits are succeeded by ordinary Wenlock shale.

West of Llanarthney in Caermarthenshire the Upper Silurian rocks disappear, and the Old Red Sandstone and Carboniferous strata lie directly on Lower Silurian beds.

Old Red Sandstone and Carboniferous Rocks.—From Denbighshire to Pembrokeshire the whole of the Silurian rocks of Wales and Shropshire are set in a framework of Carboniferous and Old Red Sandstone strata. Striking from Anglesey across the entrance to the Menai Straits, the Carboniferous Limestone rests on the Bala beds at the Great and Little Ormes headlands, but from thence to Llanelidan it lies on Upper Silurian shales and flagstones in a long band rarely more than 2 miles in width. Here and there narrow strips of Old Red Sandstone intervene,* and the whole of these dip north-east into the vale of Clwyd, where the limestone is overlaid by a low expanse of New Red Sandstone. From beneath this Secondary rock on the east, thin interrupted strips of limestone again appear in contact with the Upper Silurian hilly range east of St. Asaph and Ruthin, which like a great barrier divides the limestone in the Vale of Clwyd from that on its eastern flanks. The base of the Carboniferous Limestone lies highly unconformably on the Silurian strata, and its upper beds are overlaid by the Denbighshire coal-field.

The same limestone bounds the Silurian territory as far south as Llan-y-mynych, lying on the Caradoc or Bala beds at Cyrn-y-brain, on the Wenlock shales and flags near Llangollen, and again on the Bala beds east of the Berwyns. Following the Silurian line to the south between the Breidden hills and Le Botwood in

* The strata which in places contain Cornstones have always been considered Old Red Sandstone. They, however, belong to that uppermost part of the formation which some authors now consider to be closely allied or actually belonging to the Lower Carboniferous series.

Shropshire, the Coal-measures lie indifferently on Upper and Lower Silurian and Cambrian rocks, and between Coalbrook Dale, and Llanarthney in Caermarthenshire, the Old Red Sandstone, sweeping across Herefordshire into South Wales, rests directly and apparently conformably on Upper Ludlow rocks, till in Caermarthenshire it gradually creeps across the Upper Silurian strata, and bounds the Llandeilo flags on the south as far as the eastern Cleddau, near Slebech, in Pembrokeshire. Beyond Slebech in its turn it is overlapped by the Carboniferous Limestone, and from the western Cleddau to the north-east angle of St. Bride's Bay, the Coal-measures rest directly on, or sometimes faulted against the Lower Silurian strata.

Physical Relations.—The principal physical relations of the Silurian and Cambrian strata of Wales may be briefly stated as follows:—There is no sign of unconformity anywhere between the Cambrian rocks and the overlying Menevian beds, Lingula flags and Tremadoc slates of Merionethshire, Caernarvonshire, and the Longmynd.

The beds known as Tremadoc slates succeed the Lingula flags They are best known in the district from whence they take their name, and are characterised by the presence of *genera* of *trilobites*, and *species* of *brachiopoda*, many of which are not found in the underlying true Lingula flags, and some of the genera and a few species of which pass upwards into the Arenig, Llandeilo, and Caradoc series. They have, therefore, an independent character of their own, which, however, is more nearly allied to that of the Lingula flags than to that of any overlying formation when we consider the general grouping of trilobites, and as far as it goes even of species of brachiopoda.

The Arenig slates come next in the series (Lower Llandeilo of Murchison). These are found overlying the Tremadoc slates all round the great anticlinal boss of Merionethshire, the centre of which is formed of the Cambrian grits and slates.

In that area the line of division between the Tremadoc slate and the Arenig beds is generally marked by the presence of a bed of grit (sometimes a fine conglomerate), which, first seen by the sea near Criccieth, runs from thence in curving and partly faulted lines a little south of the Moelwyns, and west of Arenig and Moel-llyfnant to the country north of Cader Idris, and south of the estuary of the Mawddach. The same grit appears on the western slope of Aran Mowddwy.

Throughout all that well marked line of division there is, however, no sign of actual unconformity. The same may be said of the Shropshire area in the district of the Stiper stones, on which, east of Shelve, the Arenig slates rest. There, however, the presence of Tremadoc slates has not yet been proved, while Lingula Davisii has been found in the slaty beds between the Stiper stones and the purple gritty series of the Longmynd.

The absence of the Tremadoc slates, if proved, in this area may be very significant.

At St. David's the Arenig slates are well developed without any sign of unconformity to the Tremadoc slates and other underlying strata.

In the passes of Nant Francon and Llanberis, and the adjoining hills, though the Lingula flags are well developed, no Tremadoc slates have yet been proved, but westward of that region between Penrhyn Park on the N.E., and Caernarvon and Dinlle on the S.W., there is a long strip of slaty ground which, as far as the palæontological evidence goes belongs to the Arenig series, *and which lies directly on the altered strata of Bangor*, which there is every reason to believe are the equivalents of the Cambrian grits and conglomerates of Nant Francon and Llanberis, and probably of a low part of that series.

Neither have any strata so low as the Lingula flags been found in Anglesea, while Caradoc, Llandeilo, and Arenig slates, are well known, lying upon metamorphosed Cambrian strata the general equivalents of those of Bangor.*

In the Lower Silurian strata above the Arenig slates, there is in Wales no sign of unconformity till we reach the Upper Llandovery rocks, which form the base of the Upper Silurian series.

Classification of the Llandovery beds and Tarannon shale.

The next point that arises is the relation of the Lower Llandovery beds to the older strata. These, as already stated, appear on the east side of the Bala series, south-east of Bala, whence striking south in a well-defined strip to Mallwyd, they gradually thicken and widen out, and rolling over to the westward, they seem to form a large proportion of the rocks of Cardiganshire, West Montgomeryshire, Radnorshire, North Caermarthenshire, and part of Pembrokeshire. In general they are almost unfossiliferous, but between Rhayader and Builth, and near Newbridge, and in Caermarthenshire, between Noeth-grug and Llandovery, they contain numerous fossils. Sometimes they seem to pass lithologically into the Caradoc or Bala beds, both in South and North Wales, and no unconformity has been detected between them. In the original typical country of the Caradoc sandstone of Sir R. Murchison in Shropshire, the Lower Llandovery beds do not exist. These considerations, added to the circumstance that the greater proportion of the fossils are Lower Silurian species, decided the Geological Survey to retain these strata among the Lower Silurian deposits, although by some persons it has been proposed to place the Lower and Upper Llandovery beds in a Middle Silurian series.

The Upper Llandovery beds come next in the series. In South Wales they first appear in Marloes Bay, and, at intervals, range across Pembrokeshire; but further north and east they

* In Sutherlandshire and in Ireland there is a marked unconformity between the Llandeilo and Caradoc beds and the underlying Cambrian rocks, the Tremadoc and Lingula flags being absent, and the same is the case in Caernarvonshire, near the Menai Straits, and in Anglesey.

disappear for a space, being overlapped by the Old Red Sandstone. They re-appear south of Llandeilo, in Caermarthenshire, lying at the base of the Upper Silurian rocks; and varying from a few feet to 1,000 feet in thickness, they range north-east in a narrow strip through parts of Caermarthenshire, Breconshire, and Radnorshire, lying indifferently and unconformably on Lower Llandovery, Caradoc, and Llandeilo beds. Near Builth, only a few feet thick, they rest quite unconformably on the Llandeilo flags and their associated igneous rocks. They are also found near Presteign, at Nash Scar, and in Shropshire they lie very unconformably on the Caradoc sandstone between the neighbourhood of Cardington and Coalbrook Dale. In the Longmynd country they also lie quite unconformably in the form of a calcareous conglomerate on Cambrian and Lower Silurian rocks, and beyond this in Wales they are not known anywhere at the western base of the Upper Silurian strata between Radnorshire and the mouth of the Conwy.

While the general conformity of the Lower Llandovery beds with the Lower Silurian strata points to a relationship between them, the decided unconformity of the Upper Llandovery beds on all below, indicates a close connexion of these strata with the Upper Silurian rocks generally. In fact a great physical break takes place at this point, all the lower members of the Silurian series having been disturbed and planed across by denudation before the Upper Llandovery beds were deposited upon them. Accordingly, by the Geological Survey they are considered to form the basement beds of the Upper Silurian strata of England and Wales.

Though the Upper Llandovery beds do not occur in that part of North Wales which forms the main subject of this memoir, the foregoing explanation is necessary for the full understanding of the subject. The stratigraphical classification adopted in consequence of the physical relations of the strata is confirmed by the fossils.

The Tarannon shale, which comes next in the series, ranges from Caermarthenshire on the south to the mouth of the Conwy. It rises generally in a narrow band from beneath the western base of the Wenlock shale and Denbighshire grits. In the country near Llandovery (Noeth Grug, &c.) and west of Builth the shale lies directly, and apparently conformably, on the Upper Llandovery beds. A little further north the Tarannon shales gradually overlap the Upper Llandovery strata, and between that point and the mouth of the Conwy in North Wales they lie transgressively and therefore unconformably on various members of the Lower Silurian series. On the other hand, both in Wales and Shropshire they pass conformably under the lowest beds of Wenlock shale, with which undoubtedly they are intimately connected.

Above the Tarannon shale the Wenlock and Ludlow beds seem to have been deposited in regular and unbroken succession, only varied here and there by the presence of bands of limestone, as for example, in the Wenlock and Aymestry region in Shropshire

The strata that lie between the top of the Caradoc or Bala beds and the base of the Wenlock shale, were, in my opinion, formed during a period of occasional oscillation of the relative levels of the land to the sea. This oscillation succeeded the long and continuous deposition of the Bala beds, and preceded the formation of the Wenlock and Ludlow strata. The Lower and Upper Llandovery beds and the Tarannon shale belong, in fact, to what in a restricted sense may be termed a middle portion of the Silurian epoch. Three fragments of this episode have alone been preserved, and while the oldest, that of the Lower Llandovery beds, is closely connected with the Lower Silurian period, the remaining two are more nearly related to the Upper Silurian age.

To explain all of these phenomena that apply to North Wales more in detail, will be one of the principal objects of this Memoir; and in doing this I shall not invariably follow either an ascending or a descending stratigraphical order, nor yet describe the details of each entire section in succession, but rather allude to their points and peculiarities in any mode most desirable for the elucidation of the physical geology of North Wales.

CHAPTER III.

The Cambrian Rocks of Merionethshire.*

General Range.—The Cambrian rocks of Merionethshire are comprised in a broad mountain tract, forming an irregular oval, of which the widest diameter from north to south is about 15 miles, and that from east to west about 10 miles.

The rocks of this region principally consist of coarse quartzose, greenish grey grits, the quartz grains being sometimes associated with interspersed granules of felspar. The rock has often a semi-crystalline aspect, perhaps due in most cases to the original angularity of its component grains, and in others to the partial effect of what is termed metamorphic action. The beds seemed to have been formed partly by the direct waste of rocks of a granitic character, or at least into the composition of which quartz and crystalline felspar largely contributed. Occasionally the strata are conglomeratic, quartz, and more rarely felspathic pebbles, being disseminated in a gritty base. They are always hard and solid, and often very massive, attaining a thickness of 8, 10, or even 12 feet. Fine sections are so numerous that almost anywhere their general structure may be examined. Sometimes they are purple and fine grained, and they are intermingled with occasional bands of greyish green and purple slates, which, especially towards the

* Map 75, N.E., S.E., and 59 N.E.

lower part of the series, attain a considerable development. Excepting Annelide tracks and borings, no fossils have yet been observed in the Cambrian strata of Merionethshire.

Sections—The Cambrian rocks are bounded by a sinuous line from Barmouth to Dol-y-melynllyn,* near the fifth milestone north of Dolgelli. From thence it bends north, crossing the turnpike road and Afon Eden near the sixth milestone, and Afon Gain close above Rhaiadr Mawddach. Beyond this it passes along the east slope of Craig-y-Penmaen, and afterwards, partly bounded by a north and south fault, the line crosses the Ffestiniog road about a mile north-east of the spot where the roads branch to Ffestiniog and Maentwrog. A few hundred yards further north, the boundary suddenly leaving the line of fault, strikes to the south-west by various houses called Llenyrch, Dolorgan, and Glyn-cywarch, after which it enters the marsh of Morfa Harlech, and bending to the north beneath the alluvium, again takes a westerly course on the hilly ground by Llanfihangel-y-traethau, and passes from Bryntirion towards the blown sand west of Glan-y-mor. From thence to Barmouth it is bounded by the marsh and the sea, but under water the boundary perhaps strikes westward towards the promontory of Penrhyn-du on the north coast of Cardigan Bay.

Near Barmouth the strata are beautifully exposed on the hill sides towards Aber-rhamffroch, dipping E.S.E. at angles of about 50° and 60°. They are composed of coarse quartzose grits of a grey colour, with a tinge of green. Semi-transparent grains of blue quartz are common in these. Throughout the whole section there are thin bands of greyish green and occasionally of purple slate, a good example of which occurs near the old ferry, close by the landing place. The passage into the Menevian strata, afterwards to be described, is well seen at Aber-rhamffroch.

Another beautiful section occurs about 5 miles north-east of Barmouth, on the west side of Y-foel-fechan, where, on a high and steep hill side there is a clear exposure of these rocks, bed after bed dipping south at low angles over a distance of about a mile. On Clogau the beds maintain the same dips, and from thence to Pont-ar-Gamlan they gradually curve round and dip south-easterly under the Menevian beds of Cwm-gwain and Cefn-coch. From Pont-ar-Gamlan towards Trawsfynydd they dip nearly east, and all these dips being on an average greater than the slope of the hills, lower beds gradually crop out on the north and west. A broad anticlinal axis runs up the centre of the great flats, that extend from the north end of Cefn Cam to Cors-goch near Trawsfynydd, and this arrangement of the beds immediately north of Craig-y-ganllwyd and Cefn Cam, is well shown in the horizontal sections, sheet No. 37, lines 1 and 2. In this part of the area the lowest Cambrian beds run north to Dolwen, where they are concealed by drift and alluvium, but judging by the superficial débris, they probably consist in part of purple slate. A curved line

* Mis-spelt *Dol-y-melynen* in the map.

drawn from thence, averaging about 5° west of south, would give the continuation southwards of the lowest exposed beds of the Cambrian anticlinal curve. On the rough hills, traversed by the Roman road, on the east side of the anticlinal, great beds may be seen rising in terrace-like steps, dipping east, at angles varying from 25° to 30°. The same beds roll over to the west, forming the magnificent mountain escarpments of Llether, Rhinog-fawr, Rhinog-fach, and Craig-ddrwg, where the strata dips towards the sea, and so barren are the rocks that even from the Dolgelli and Ffestiniog road, on a clear day, layer above layer may be followed by the eye along the whole eastern face of the mountains.

In the pass of Bwlch-drws-ar-dudwy, the rocks are singularly bare of vegetation, and for a height of about a thousand feet from the base to the very summit of the hills, the beds piled on each other may be seen dipping steadily west, with gentle undulations, at angles varying from 25° to 30°, presenting one of the grandest spectacles, both geologically and as a piece of rugged scenery, that North Wales affords. Rhinog-fawr forms one side of this pass, and the disposition of its rocks will be well understood by reference to the horizontal section Sheet No. 37, line 1, on a scale of 6 inches to a mile.* From thence to the sea the beds undulate, so that the strata that crop to the surface about the centre of the Merionethshire anticlinal line on Afon Eden rise again near Harlech, and for some miles further south. Purple and dark purplish blue slates occur near the coast and in several of the valleys south of Harlech. Towards Ffestiniog the same grits dip northerly,† the east bend of the curve being cut off by a large fault,‡ so that the Cambrian strata and the Lingula beds abut on each other, both dipping to the north at angles under 30°. In the centre of the great anticlinal curve purple slates, underlying all the grits, rise in mass sufficient to allow of the opening of small quarries, but the form of the ground being generally unfavourable for such operations, the depth of slate is unknown. In most of the greater sections conglomerates occasionally occur, and false bedding, together with ripple or current marks are not unusual. The greatest measured thickness is from 6,000 to 7,000 feet, but the base of the formation is unknown, either on the coast or in the anticlinal curve, between Trawsfynydd and Cefn Cam.

The total thickness (Section 3, Pl. 28) between Trawsfynydd and the Silurian beds on the N.W. is about 4,200 feet, while near Rhinog-fawr the Cambrian grits exposed at the surface attain a thickness of about 6,300 feet.§ Either, therefore, lower beds rise to the surface in that district, or else the grits and conglomerates rapidly thin out northwards. The last supposition is most probable, for not only are the same slaty bands characteristic of the

* When *sheets* of sections are mentioned in this memoir, they always refer to the large 6-in. sheets published by the Geological survey in illustration of the maps on a scale of 1 inch to a mile.

† Map 75 N.E., and Section, sheet No. 28, at Corsgoch, line 4.

‡ Map 75 N.E. and S.E., and Section, sheet 29, line 1. *See also* page 23.

§ Section, sheet 37, lines 1 and 2, on a scale of 6 inches to a mile.

whole of the lower part of the anticlinal curve from near Cefn Cam to Trawsfynydd, but it will subsequently be seen that still further north, near the Menai Straits, the uppermost Cambrian grits resting on purple slates do not attain more than a fourth part of their thickness near Trawsfynydd.

Porphyry and Greenstone.—Intruded amongst the lower beds are masses of porphyry, formed of small granular crystals of quartz, set in a compact blue felspathic base, like that afterwards to be described in connexion with similar rocks at Llanberis. Two of these lie in the district of Crawcwell, a few miles south-west of Ffestiniog, the others near Hafod-gan, and on Cefn Cam still further south. The rocks in contact with them are altered, and the porphyries, like granites and others of their class, present the appearance of rocks that have cooled and consolidated deep beneath the surface.

An immense number of trap dykes traverse these rocks. They are especially numerous in the Cambrian grits and overlying Silurian beds of Llawllech, and also to the north and north-east as far as Cefn Cam and Craig-y-ganllwyd, but towards the sea, west of the escarpment of Rhinog-fawr, the ground is much obscured by drift. On and about Llawllech the dykes more or less follow the line of strike, but elsewhere they run in many directions, and frequently almost at right angles to the bedding. Some of them form continuations of lodes and lines of fault, a remarkable instance of which occurs west of Tyn-y-groes. There between Perthlwyd and Cefn-coch, a quartz lode bearing lead, which is also a fault, separates the Cambrian and Menevian strata for about three-quarters of a mile. Between Cefn-coch and Craig-y-cae it is only recognized as a vein of quartz, and from thence to the neighbourhood of Cwm Mynach-uchaf the same fissure, ranging east and west for more than a mile, has been filled with greenstone. The dykes also form a marked feature of the ridges north of Rhinog-fawr, generally running north-west and south-east, and cutting across the strike of the massive beds of greenish coloured grits. They rarely exceed 2 miles in length, and are mostly dark coloured, and very hornblendic; but some of them, especially among the higher beds of the formation, consist of a pale grey rock, which is sometimes slightly calcareous. In several instances the dykes were found to be so strongly magnetic, that while standing on them and making observations with the compass, its play was completely deranged, and the observed bearing misled Mr. Selwyn and myself as to our position on the map, and so strong was the power of attraction in a pointed fragment of the stone, that when brought nearly in contact with the glass of the instrument, the needle and card spun round as if under the influence of a bar of steel. A well marked example of this occurs in the dyke cited above that occupies the same fissure with the lead lode and quartz vein west of Tyn-y-groes.

CHAPTER IV.

General Distribution of the Menevian Beds, Lingula Flags, Tremadoc and Arenig Slates and associated Igneous Rocks of Merionethshire.

General Description.—Menevian Beds, Lingula Flags, and Tremadoc Slate.—The Cambrian grits occupying the oval tract described in last chapter* are succeeded by the above-named subformations, and these by higher Silurian rocks, which, throughout a broad horizon, are largely intermingled with igneous products, the whole circling round the Cambrian Strata on the south, east, north, and north-west. Beginning on the south near Barmouth the Menevian, Lingula, and Tremadoc beds occupy the minor hills on both banks of the estuary to and beyond Dolgelli, from whence they strike northward towards the western part of Mignent and Ffestiniog, and then westerly and south-westerly to the neighbourhood of Tremadoc and Morfa Harlech. The junction of the Menevian with the Cambrian rocks is well seen at Aber-rhamffroch about half a mile east of Barmouth.

There is no unconformity. On the contrary there is a perfect passage in some 20 or 30 feet of strata well exposed on the roadside. These dip at a high angle a little to the south of east, and consist of purplish slates merging into the dark blue Menevian slates which again pass into the ordinary pyritous slates, typical of the lower members of the Lingula flags over the greater part of North Wales. In spite, however, of conformity and the apparent passage, the lithological differences of the greater masses on either side of the line are well marked. This circumstance, and also that all traces of life excepting annalide tracks are as yet unknown in the Cambrian rocks of Merionethshire,† while there is a speedy appearance of life in the overlying blue slates, would seem to afford sufficient grounds for this stratigraphical separation, and the employment of different colours to represent it on the map.

The Menevian, Lingula, and Tremadoc beds occupy most of the country between the Cambrian strata and the Arenig beds which are associated with the interbedded igneous rocks of Cader Idris, the Arans, Arenigs, and Moelwyn.

Though there is a stratigraphical passage between them, the Lingula flags assume a somewhat different lithological aspect from that of the Menevian strata for though sometimes equally dark, yet the Lingula flags are generally lighter coloured, and coarser grained both as regards the general diffusion of sandy material and also in the occasional occurrence of distinct beds of grit. As a whole they may be described as banded flags, formed by the

* Sheets 59 N.E., 60 N.W., 74 S.W. and N.W., and 75 S.E. and N.E.

† A closer search among the finer grained sandstones and slates may possibly yield fossils similar to those found in the rocks of the Longmynd, and at St. David's.

repetition of numerous very thin, slightly wavy felspathic-looking and siliceous layers, of a light bluish grey colour. Ripple or current marks are frequent on the flaggy surfaces, apparently indicating that the strata were accumulated in water of moderate depth.

The commonest fossil of these beds is the shell discovered by Mr. E. Davis at Tremadoc, and after him named *Lingula Davisii* by McCoy. It is a large broad species, and occurs plentifully throughout the whole of the Lingula flags, particularly in this area on the left bank of the Mawddach, where it was detected by Professor Sedgwick, who in the year 1846 explained the identity of these beds with the Lingula flags of Tremadoc. In the same year it was found near Dolgelli by Mr. Selwyn, in the woods of Garth and in the hills above Llyn-y-Penmaen, accompanied by a crustacean, *Hymenocaris vermicauda* (Pl. 2, figs. 1 to 4). A trilobite, *Olenus micrurus* (Pl. 2), was discovered lower in these strata, by Mr. Selwyn at Cwm-Eisen, towards the base of the Lingula flags, and it occurs near Dolgelli, Tremadoc, and other places. Many more trilobites have been found near Tyn-y-groes, Dol-y-melynllyn, and Pont-ar-Gamlan, and also near Tremadoc, which will be mentioned further on, and doubtless these and other distinctive fossils will be found in many other places if properly searched for.

The Lingula beds of Merionethshire are everywhere overlaid by Tremadoc slate, which in their turn in the same area are overlaid by the Arenig beds, which all round the great anticlinal boss from Cader Idris to the Moelwyns, are interstratified with masses of volcanic ashes and beds of felspathic lava. Unlike these volcanic ashes and porphyries, which lie in a well-marked horizon, the igneous rocks of the Menevian, Lingula, and Tremadoc series are discontinuous and patchy, arising from the circumstance that they consist of dykes and intrusive masses, chiefly of varieties of greenstone. These occupy large spaces between the estuary of the Mawddach and Cader Idris, and great masses occur south of the river, where it bends to the east between Rhaiadr Mawddach and Craig-y-Dinas. They also occur among the breccias of Rhobell-fawr, itself one of the greatest igneous masses within the area of the Lingula flags. They are also very numerous between the road from Ffestiniog to Bala and the eastern bed of the Mawddach north of Rhobell-fawr. Excepting in the neighbourhood of Dolgelli, intrusive bosses are comparatively unknown in the Tremadoc slates and the overlying volcanic series.

Igneous Rocks.—The great interbedded volcanic masses already adverted to, constitute the loftier mountains of the district, forming the ranges of Cader Idris and Aran Mowddwy; and west of the Bala road, the same rocks, repeated by a fault, run from Penmaen to Arenig (Fig. 8, p. 37, and Pl. 28, sec. 3), beyond which they spread to the eastward by Mynydd Nodol to Craig-ddu, and thence with a very irregular outline to the hills around Llyn Conwy, beyond which they bend by Moelwyn to the south-west towards Llanfrothen, on the borders of Traeth-mawr. On the south-east

and south the strike of the upper boundary of these rocks sometimes displays great regularity, but further north the line is more curving, irregular, and broken by numerous faults. They consist principally of varieties of felspathic rocks, generally divisible into consolidated ashy beds and felspathic porphyritic lavas. These are regularly interbedded with each other and with the Arenig slates, and from their structure, arrangement, and effect on the strata, they are to an experienced eye easily distinguishable from intrusive rocks in the ordinary sense of that term. Their greatest development is on the east and south, between the Arenigs, the Arans, and Cader Idris. Throughout these ranges south of Arenig, the ashy beds chiefly lie in well-defined strata below the felspathic lavas, and all the non-intrusive igneous rocks of Merionethshire have been formed in that stage of the Lower Silurian period corresponding to the Arenig slates.*

Though at first sight we might be apt to suppose that much confusion would prevail in a highly disturbed country where igneous rocks so much abound, yet when carefully dissected the structure is found to be comparatively simple, resolving itself into certain definite slaty masses interstratified with bedded ashes and lavas, which have subsequently been complicated by contortions and faults. The published 6-inch sections prove this point, and by their aid and that of the illustrations that accompany this Memoir, I shall endeavour to make it plain.†

Lingula Flags, &c. north of the Estuary of the Mawddach.—I shall now describe the minuter structure of the strata between the Cambrian grits and the estuary of the Mawddach.

On the eastern slopes of Llawllech, Section No. 1, Pl. 28,‡ the Cambrian rocks are composed of the usual hard and generally thick-bedded greenish grey coarse grits and conglomerates, with occasional thin interstratifications of dark blue and purplish blue slate. The grits are often very felspathic, and the grains both of felspar and quartz being frequently imperfectly angular, impart a somewhat crystalline aspect to a freshly-fractured surface of the rock.

Between Llawllech and the neighbourhood of Y-fron-heulog the section crosses the same set of beds as those that are so beautifully exposed at Aberrhamffroch on the coast, about half a mile east of Barmouth, where the total thickness of the Menevian strata, which conformably overlie the Cambrian grits, is apparently between 50 and 60 feet.

A long synclinal tongue of these beds forms Banc-y-frain, and runs to the very summit of the ridge of Llawllech overlooking Llynbodlyn. At this point I found small *Lingulæ*, unfortunately not preserved, but which may probably have been of the species well known at St. David's, called by Mr. Salter *L. ferruginea*. Like the neighbouring Cambrian rocks, this tongue is intersected by a number of greenstone masses, which run principally along the line of strike. At its south-eastern boundary the basement line turns sharply to the north-east, and from thence trends along the flanks of the hill north-west of Llanelltyd. The average dip is south-easterly, with various undulations, the nature of which, together with the arrangement of the Cambrian grits of Llawllech, will be best understood by reference to Pl. 28, No. 1, or to the Horizontal Section Sheet 26, line 2. The rocks are frequently much cleaved, the dip of the cleavage being towards the south-east and north-west, but more

* The only exception is, where a small part of a later series of volcanic rocks occurs, in that corner of Merionethshire that lies east of Beddgelert and Pont-Aberglaslyn.

† Sheets 26, 28, 29, 31, 37, and sections 1 and 3, pl. 28.

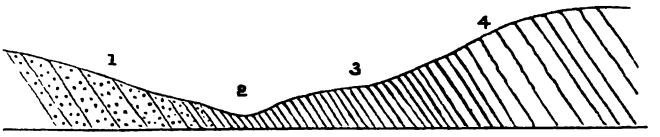
‡ *See also* 6-inch Section, Sheet 26, lines 1 and 2.

frequently the former, in accordance with the average dip of the strata. Its angles vary from 75° to 95°. Above these, and lithologically passing into them, dark grey and blue slaty Lingula flags occupy nearly the whole of the right bank of the estuary of the Mawddach as far as Llanelltyd, the decomposition and oxidation of disseminated crystals of iron pyrites giving a rusty tinge to the rocks and soil, and originating the name of a place (Cae-goch, or the red field) near the village. Beyond Llanelltyd the same beds strike more northerly, following the general line of the Cambrian strata, and occupying both banks of the river by Dolmelynllyn to Rhaiadr Mawddach. The red ferruginous hue of the Lingula beds is strikingly manifested in the cliffy hills of Penrhos opposite the little inn of Tyn-y-groes, where the strata contain numerous remains of species of *Agnostus*, *Olenus micrurus*, &c.

Near Dolmelynllyn, in the river Camlan, close above the bridge, the junction of the Cambrian and Menevian strata is clearly exposed, and as at Aberrhamffroch near Barmouth, their precise limits are indefinite, but a few yards across the strike settles the matter. They dip nearly east from 40° to 60°, and there is neither unconformity nor any sudden lithological break between the strata. A greenstone dyke, cutting the Cambrian grits in the line of strike, crosses the river a little above the bridge, and the regularity of the dip is there disturbed.*

The general succession of the strata at Pont-ar-Gamlan is shown in the following diagram :—

Fig. 2.



1. Grey Cambrian grits.
2. Menevian beds.
3. Dark slaty Lingula beds.
4. Flaggy grey ripple-marked Lingula flags.

At the upper part of No. 1 blue slaty interstratifications begin to appear among the grits for a few yards, and these pass by lithological gradations into the Menevian strata 2, which here contain *Paradoxides Hicksii*, *Microdiscus punctatus*, and *Conocoryphe* sp. Lithologically the uppermost Menevian beds pass conformably and insensibly into the lowest Lingula beds, in which are found *Olenus gibbosus*, *O. cataractes*, *Agnostus nodosus*, and *A. princeps*, and these are succeeded by the flaggy-banded and ripple-marked strata of the same series numbered 4, which are well seen in the Mawddach at a wooden foot-bridge across the river about half a mile north of Pont-ar-Gamlan. There they dip at an angle of 45° a little south of east, and from thence an ascending section of the Lingula flags, rich in Linguläe, may be followed eastward by Moel Hafod Owen to the fault that bounds the western slope of Rhobell-fawr, and beyond that up the higher part of the Mawddach by Craig-y-Dinas to beyond Rhiw-felyn.

Between Barmouth and Rhaiadr Mawddach the Menevian and Lingula beds are penetrated by more than 150 intrusions and dykes, varying from a few yards to nearly a mile in length. A large igneous mass more than a mile in length and three-quarters of a mile in width, forms the heights of Hafod-y-fedw, between Tyn-y-groes and the third milestone on the Dolgelli road. The greater part of Moel Cynwch consists of the same kind of rock, and also a large part of the hills between Tyn-y-Penrhos and Rhaiadr Mawddach.

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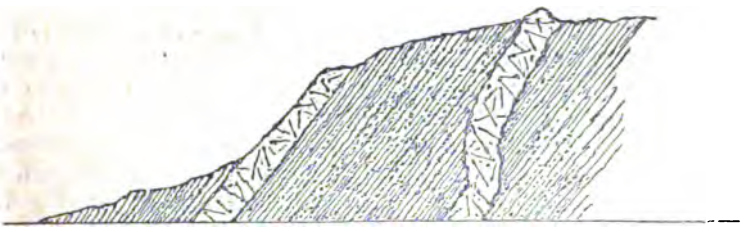
* One of the horizontal sections (Sheet 37, line 2) crosses the boundary line about 2 miles farther north, nearly half a mile south of Rhaiadr Mawddach. The same easterly dip prevails, and the rocks of the neighbourhood (which south of Moel-hafod Owen are talcose) are in part altered and otherwise affected by intrusions of greenstone.

When these masses are tolerably large they are occasionally columnar, the columns generally lying at right angles to the inclination of the dykes. Many of them are imperfectly crystallized and light coloured, owing sometimes to the presence of a considerable proportion of felspar. In many others their character is somewhat peculiar, in so far that instead of being principally constituted of ordinary dark green hornblende, they chiefly contain a pearl-grey variety, and most of them are so calcareous that they effervesce briskly with acids.

Unlike the majority of the dykes that pierce the neighbouring Cambrian grits, those in the Lingula beds often show a tendency to run in or nearly in the line of strike (notwithstanding that in many cases they pass distinctly across it), and it is not impossible that this may partly arise from the circumstance that the massive Cambrian strata are much jointed, and were fractured irregularly when the formations were disturbed; whereas in the softer and more yielding Lingula beds the intruded matter may have been apt to insinuate itself between the lines of bedding. On the other hand, it is highly probable, though cannot be certainly proved, that the straight narrow dykes, which in North Wales generally run more or less north-west and south-east, are of much later date than those which are apt to run approximately in the lines of strike. It seems to me indeed to be probable that the north-west dykes are of post-carboniferous age, like some of those in Anglesey and the Caernarvon shore of Menai Straits.

On the sides of the hills the dykes in the Menevian and Lingula beds frequently rise in broad flat surfaces, dipping at high angles often in or nearly in conformity with the inclination of the strata, in the manner shown in the accompanying diagram No. 3 in Dyke No. 1.

Fig. 3.



1 2

Hence, when beginning the examination of the country, it was supposed that these were beds of igneous matter spread contemporaneously with the deposition of the mud and sand that formed the lower beds of the Lingula flags.* This position, however, became untenable when it was observed that, though the majority run in or nearly in the strike of the country, they yet are apt to break athwart the beds at small angles (No. 2), and sometimes (like the dykes in the Cambrian grits) to cut across the strike altogether. Good examples of such dykes may be seen on the turnpike road between Dolgelly and Barmouth. The pierced rocks are often slightly bleached and hardened at the points of contact.

* *See* Memoir by Messrs. Jukes and Selwyn, Geol. Journal, vol. 4, p. 300.

CHAPTER V.

The Lingula and Tremadoc Beds south of the Mawddach, and the Range of Cader Idris.

General Description.—The Cambrian and Menevian beds of Barmouth pass out to sea with a S.S.W. strike, and do not appear on the south side of the estuary where a part of the Lingula flags forms the cliffy slope of Gallt-ffynnon-yr-hydd overlooking the sea. They consist of the usual banded flaggy beds dipping E.S.E. in wavy lines at angles of from 30° to 50°. These are overlaid by the dark blue slates of the Upper Lingula flags, which in this neighbourhood have been repeatedly but not always successfully worked for slates in quarries of considerable extent.

The dark blue strata are overlaid by grey Tremadoc slates, and the whole, west of the base of the Arenig series, strikes southerly from the neighbourhood of Capel Arthog to the alluvial flat and estuary of the Dysynni between Peniarth and the mouth of the river. The great Bala fault which passes down this valley here runs out to sea, and being a down throw on the S.E. cuts off on the land the whole of the strata described above.

From Dolgelli to the sea opposite Barmouth, with various undulations, the general dip of all the beds is south and south-easterly, at angles averaging from 40° to 60°; and from the Cambrian rocks on the right to within a mile inland of the left bank of the estuary the section seems to maintain an unbroken ascending order. Eventually the slaty rocks plunge beneath the igneous masses that form the range of Cader Idris (Pl. 28, Fig. 1).* As on the opposite bank of the estuary, dykes and thick sheets of greenstone, more or less intruded between the beds, are common in the line of strike.

Instances occur on the shores of the estuary, in Garth woods, and on and near the road between Capel Arthog and Penmaen. One of them, about 4½ miles by the road from Dolgelli, is crossed by the section (Sheet 26, and Fig. 1, Pl. 28). It is slightly calcareous, short, and about 400 feet thick where crossed by the section, and, like others of its class, it slightly alters the beds for a few inches from the junction on either side, thus, even while partaking of the average dip of the beds, affording good evidence of its intrusive character.

These greenstones interfere but little with the run of the greater masses of strata. But in the higher parts of the series, near Dolgelli and Cader Idris, and far beyond to the north-east and north, the igneous rocks in great part differ from the dykes in the Cambrian rocks and Lingula flags, in so far that the green-

* *See also* Section 26, lines 1 and 2.

stones are generally on a greater scale and often run in long continuous lines over large areas. Besides these, felspathic porphyries and ashes not met with in the area before described, occupy, across a considerable width, the major part both of the surface and solid body of the country.

On the hills between Dolgelli and Aberdysynni* there are several lines of greenstone. The largest, near Capel Arthog, is five miles in length. In general they dip east, south-east, and south, following the curved strike of the Lingula flags with which they are associated. They are often very hornblendic and highly crystalline, especially on the hills overlooking Capel Arthog. A large igneous mass coloured as greenstone lies immediately south of Dolgelli. This beautiful rock is a highly crystalline compound, as shown in a large quarry by the turnpike road near Waun-hir, about a mile south-west of Dolgelli. It consists of diffused hornblendic matter and crystals of orthoclase felspar, some of which are a quarter of an inch in length. Were it not that the greenstones sometimes slightly cut across the strike and bifurcate, and also that they alter the slaty flags alike at their upper and lower margins, they might on a cursory examination readily be mistaken for contemporaneous lava beds, and the same mistake might be made with others of their kind throughout the whole of the igneous districts of North Wales. Four lines of igneous rocks occur within a mile of the coast between Llwyngwril† and Aberdysynni. The three southerly masses are of greenstone, while that at Llwyn-gwril is a beautiful dark greenish grey crystalline rock with long narrow prisms of felspar, specks of pyrites, calcspar filling nests of irregular form, an oxide of manganese, and a green mineral, which constitutes a large proportion of the rock, and is some form of Serpentine.‡ The alteration of the beds in contact with them is well shown on the hills immediately north of the mouth of the Dysynni, where parts of the Lingula flags are bleached and porcelanic, their high easterly dip, especially above Tal-y-cerrig, remaining perfectly apparent.

The general arrangement of some of the greenstones on the hills south of the Mawddach is well shown where the section crosses by Llyn-yr-Wylfa between 3 or 4 miles W.S.W. of Dolgelli (Pl. 28, No. 1, and Section 26, line 2). They are there represented dipping south-east, and at the same time cutting the strata somewhat obliquely. They are respectively about 100 feet, 150 feet, and 300 feet thick, and two of the bands are joined beneath it being inferred that this takes place at no great depth, seeing that both branches unite at the surface a little further to the south-west.

Between Llyn-creigenen and Gelli-lwyd-fawr (two miles south-west of Dolgelli) there is a great mass of felspathic trap slightly speckled with hornblende. It weathers yellow, but its fresh fracture is blue. In general it resembles the felspathic porphyry of Cader Idris, and from some points of view, looking north-east, it presents an appearance of being largely bedded with a high south-easterly dip. This is deceptive, and is due to the joints that traverse

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* On the coast, 9 miles south of Barmouth.

† Near the coast, 4 miles south of Barmouth.

‡ The above description is condensed from part of one written by Mr. Rutley. He adds: "Under the microscope the felspars are seen to be of two kinds, both "Orthoclase and Plagioclase. By polarised light the felspars in this section display "some curious examples of banding, so that in many instances it is difficult to refer "the crystal to the mono or triclinic system with any certainty. Some of the "felspars are opaque and decomposing, and in many cases dark matter has appa-"rently colonised around several spots in a crystal, causing it to show a curiously "partitioned arrangement. I think in some instances that the dark matter filling "these chamber-like spots is pyrites, but it is difficult to get good surface illumina-"tion on them. Small crystals of apatite are visible in the section, which exhibits "many good transverse slices. The matter lying between the felspar crystals is "mainly serpentine, in some places it shows a tendency to a plumose arrangement. "Chlorite may be present and some of the green matter may be some mineral allied "to serpentine. The term viridite would be the most safe name to apply to this "green matter; it no doubt represents an altered phase of augite or hornblende. "The rock may originally have been either a dolerite or a diorite. It would be "safe, I think, to call it a serpentinous greenstone."

the mass. A glance at the map shows that it lies somewhat obliquely to the actual strike of the country. Its relation to the Tremadoc slate* east of Llyn-yr-Wylfa is expressed in Pl. 28, fig. 1, F^v,† and the general inclination there indicated is well seen in the cliffs above Llyn-creigenen. Like many of the greater masses of erupted matter of a deep-seated type, it has not been injected in the form of a boss, nor yet into a mere elongated ragged fracture, but probably, like the neighbouring greenstones, it has risen towards the surface more or less between the beds, seeking a vent at some point since removed by denudation, before those latter disturbances occurred that threw both stratified and igneous rocks into their present curved and inclined positions long after the local volcanic irruptions of Lower Silurian date had ceased. At its north-east extremity it is surrounded by slaty Lingula flags. Gradually cutting its way into higher beds as it passes to the south-west, it breaks through and across a long line of greenstone and altered Tremadoc slates.

I have already stated that the Upper Lingula flags on the south side of the estuary are associated with bands of dark blue and often earthy and very pyritous slate, somewhat similar to those on the opposite shore, and these chiefly occur in the higher part of the series, and afford a roofing slate that has been quarried, often with little profit all round the anticlinal boss of Merionethshire. These dark slaty beds have been noticed by Mr. Homfray as forming the uppermost part of the true Lingula series, but having in part a fauna of their own. The occasional minute interstratifications of siliceous and more aluminous matter often seem to have debarred the development of a close and regular cleavage, and the decomposition of the iron pyrites, with which they abound, often causes the laminæ to scale off, and injures the quality of the slate.

South of Dolgelli, immediately north of Mynydd Gader, the black or dark blue slate of the Uppermost Lingula flags occurs, containing *Lingula lepis* and other fossils. This shell is also common in the Tremadoc slates which here and elsewhere overlie the Lingula beds. The position of the greenstone of Mynydd Gader (g) is shown in Fig. 7, p. 35, and it will be seen that while the black slates (1) crop from underneath this intrusive greenstone, the Tremadoc beds (2) overlie it, dipping south at a high angle. This greenstone is often beautifully columnar on its northern flanks, and breaks somewhat irregularly through the beds, thrusting short veins into the strata. The overlying Tremadoc slates, (2′) both at their junction with the greenstone and for some distance above it, are changed into a kind of porcelanite or hornstone, hard, white, and flinty when weathered. Here and there, near the igneous rock, there are numerous hard concretionary-looking nodules, sometimes rudely agate-like, and generally, like the mass of the rock, white on the surface and blue inside. These seem as if they did not belong to the original stratification, but rather as if they were the result of some kind of metamorphic action connected with the intruded igneous mass of Mynydd Gader.

The remainder of the Tremadoc slates in the high upland valley between Mynydd Gader and the northern slopes of Mynydd Moel and Cader Idris consist of grey slates, often much altered by heat, due in all probability, to numerous injected patches of greenstone (g), which never saw the light till exposed by denuda-

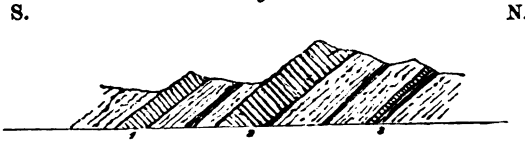
* In the earlier maps and sections and the first edition of this work this portion of the Tremadoc slate was mistaken for felspathic ashes.

† Or in 6-inch Section 26, line 2.

tion, and which here and there show at the surface in such numbers, and often so small and irregular, that on a 1-inch scale of map it is impossible to do more than indicate their general distribution, for the smaller bands are often only a few feet across. The larger ones are, however, sometimes of great thickness, and though they unite and branch into each other, and sometimes join the greater mass that skirts the base of the lofty felspar porphyry cliffs of Mynydd Moel and Cader Idris (6), they have often a tendency to run more or less in the line of the strike of the strata.

They are frequently columnar, the columns lying at right angles to the dip, as shown at 1, 2, and 3 in the following diagram :—

Fig. 4.



The flat ends of the columns, where once they abutted on superincumbent slaty strata, being now exposed by denudation, often present a beautifully tesselated aspect.

Immediately south of these minor intrusive bosses there lies beneath the steep cliffs of Cader Idris a long line of irregular broken ground forming a series of minor hills, the upper slopes of which pass into the steeper cliffs behind. Sometimes they are grassy and green, often rough, and their general character is well seen in the mounds east and west of Llyn Gafr, or on those immediately north of Mynydd Moel. In the old time Mr. Selwyn and myself felt great difficulty in coming to any definite conclusion as to the true character of these rocks. Were they volcanic ashes or of an intrusive kind? At length, but still with a feeling of great uncertainty, we included them among the former. On revisiting the country in 1874 I saw that they were very different from the ordinary felspathic ashes of Cader Idris and the Arans, and a re-examination in 1875 confirmed me in this opinion, but even now it is hard to describe and account for all the peculiarities of these rocks.

Near its western end, north of Tyrau Mawr, there is a rubbly volcanic conglomerate, above which are slaty beds with thin ashy interstratifications, mingled with short lines of intrusive greenstone, that may probably be connected with the larger mass of greenstone a little further north. Further east much of the mass is occasionally vesicular, the vesicles being sometimes filled with carbonate of lime, and the whole mass is apt to be more or less calcareous. The general base of the rock is greyish blue, and seems to be somewhat felspathic, while at the same time a good deal of hornblendic matter seems to be diffused through it, suggesting the idea that it may fairly be called a kind of greenstone.

Occasionally there are lines in it of a foot or two or even of several yards in length that suggest the idea of ashy stratification, but these are so short and accidental, and the absence of general stratification is so complete, that the mass is entirely dissimilar from the undoubted ashy beds of the neighbouring country. Furthermore, it is undoubtedly mixed with or passes into true hornblendic greenstones, some of which branch into the altered Tremadoc slates, and in its continuation N.E. of Mynydd Moel towards Bwlch-goch, the slaty rocks that overlie it have been porcelanised or *baked*, as if by the heat of an intrusive melted mass. Again, its highly vesicular character is against the hypothesis of its consisting of bedded ashes. Vesicular trap dykes are not uncommon, and if this mass be intrusive this vesicular character may perhaps be accounted for by the presence of infiltrated water in a volcanic centre deep beneath a crater, in the manner explained by Mr. Scrope, where he shows that volcanic eruptions are due to the expansion of steam which gets mixed with melted matter far below the vent.

Felspathic porphyries, Ashes, &c.—The ashy beds and porphyries of Cader Idris and other areas from the Arans to Moelwyn are of great extent and thickness, and play an important part in the igneous series. In the horizon of the Arenig slates, which lie south of the greenstone just described, they begin on a small scale on the south-west, and, sometimes interrupted by faults, extend from the neighbourhood of Llanegryn (11 miles south-west of Dolgelli) round the south-east, east, and north of the Merionethshire anticlinal curve. For the most part they are associated with contemporaneously bedded* felspathic lavas, and the presence of the ashes, in mapping lends great aid in the separation of the lava-flows from occasional intrusive felspathic masses, similar or identical with them in lithological structure. In many other points besides, the working out the solid geology of the lower igneous series of North Wales materially depends on the distribution and identification of special horizons of the volcanic ashes. The general arrangement of the rocks in which this series lies south of Barmouth is as follows (Fig. 5), not far from where in Merionethshire the bedded volcanic series of rocks thin out and disappear.

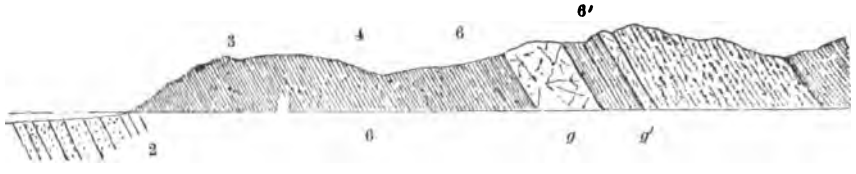
Less than a mile north-east of Llanegryn they consist of two sets of beds separated for the space of about 2½ miles by an interstratified band of slate. The ashy beds then coalesce, either by the thinning out of the slate to the north, or more probably by the gradual passage of that rock into ashes, owing to the admixture of volcanic materal, for the boundary lines are not always definite. The following diagram will explain their arrangement.

* Used in the sense of lava-flows, contemporaneous with the formation of the Silurian marine strata among which they lie. The proof that the rocks termed ashes are so, is necessarily deferred till they have been described more at length.

Fig. 5.

SECTION FROM THE SEA OVER PEN-GARN AT THE MOUTH OF THE ESTUARY, SOUTH SIDE.

N.W. Gallt-ffynnon-yr-hydd. Pen-garn. S.E.



1. Cambrian grits.
2. Menevian beds.
3. Lingula flags.
4. Tremadoc slates.

6′. Arenig conglomerate.
6. Arenig slates.
7. Felspathic ashes.
g & *g′*. Greenstones.

The rock (No. 7) consists of very calcareous brown and green sandy felspathic ashes, but further north between the Llwyn-gwril river and Pen-y-garn they are very felspathic and compact, and from thence towards Ffordd-ddu after the junction of the two they are more flaky. Further south there is a small band of greenstone on its east side, near Allt-lwyd, and another more than 3 miles long (*g'*), which, north of Pen-y-Crûg, skirts the ash on the west, separating it from the partially altered Arenig slates that lie between the ash and the long base-line of Arenig conglomerate and grit that divides the Arenig slate from the Tremadoc slate below. This greenstone then cuts across the strike of the ashy beds by degrees, and terminates against the felspathic trap of Llyn Creigenen.*

North-west of Pen-y-garn the sea cliffs of Gallt-ffynnon-yr-hydd† are in the Lingula series (No. 3), and taking this in connexion with the strike of the junction beds at Barmouth, there can be no doubt that nearly the whole thickness of the Tremadoc and Lingula flags is comprised in the space between the larger greenstone dyke and the sea, and unless the flags be prolonged beneath the sea by undulation, the Menevian beds and Cambrian grits (Nos. 2 and 1) must form the bed of the sea somewhat west of the cliff, in the manner shown in the diagram. Possibly the sunken reef of Sarn-y-bwch, opposite Aber-Dysynni, may partly indicate the continuation of the Cambrian rocks, since the strike continues in that direction. Further south it is needless to speculate, for the whole is modified by the Bala fault that probably passes through Tal-y-llyn, down the valley of Afon-felindre to the sea. It is a downthrow on the north-west. South of this fault, on the hills between Aber-Dysynni and the Dovey, higher beds by degrees come in. The probabilities, therefore, are that beyond this point the outcrop of the Cambrian rocks may lie far out at sea.

At Ffordd-ddu, nearly 2 miles south of Capel Arthog, the upper boundary of the ashes crosses the road. A very dark blue slate with pisolitic iron ore overlies it. These strata belong to the Arenig beds, and the iron ore occurs more or less, associated with the volcanic series all along the strike of the Cader Idris rocks, and is apparently the general equivalent of similar ores near Tremadoc. The dark colour of the slate gives the name of Ffordd-ddu, or the black road, to the place now described. From thence this ash, much widened and invaded by greenstone, strikes north-east to the lakes of Llyn Creigenen, where it seems to have been altered by contact with that rock and the great mass of intrusive felspathic porphyry that forms the northern borders of the lakes. Beyond this, still associated with greenstones, it runs towards the third milestone, near which it is cut off by the branching mass of greenstone and a fault, that passes from this point by Dolgelli probably as far as the sixth milestone on the Bala road. Not only has this part of the ashes been penetrated by branching greenstones, but the felspathic porphyry already described, cutting across the ashes at and north-east of Llyn Creigenen, also seems to indicate the prior origin of these ashy strata to the intrusion of this particular mass. At the point crossed by the section‡ the fault mentioned above is probably a downthrow on the north-west. On its south side is an area occupied by felspathic porphyry of about a mile in length, *F*, Fig. 1, Pl. 28. It is bounded on the south by greenstone and that curious vesicular and amygdaloidal rock already described at p. 31, while on the east it abuts on part of the altered Tremadoc slates that lie between Mynydd Gader and the lower northern slopes of Cader Idris. How the fault ends on the south-west is uncertain, but above the bulk of the ashes there is a large mass of rough felspathic porphyry, which seems to break across the strike of the beds on the cliffs on either side of Llyn Cyri, and spreads by Mynydd Pennant over a broad tract towards Llanfihangel-y-Pennant, where it branches to the east, partly interrupted by a small north and south fault that throws the rocks down on the west between Rhiwgyriedydd and Tyrau-mawr.§

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* For these details *see* 1-inch map 59 N.E.

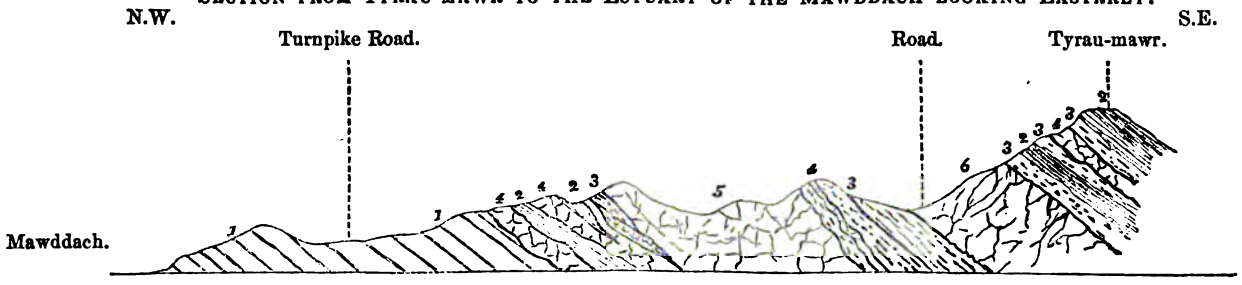
† 2½ miles south of Barmouth.

‡ *See* Map 59 N.E., ¼ of a mile south-west of the third milestone. Section Sheet 26, ine 2, near the Dolgelli and Towyn roads, and Diagram No. 1, Pl. 28.

§ On the Cader Idris range, 4 miles south-west of Dolgelli.

Fig. 6.

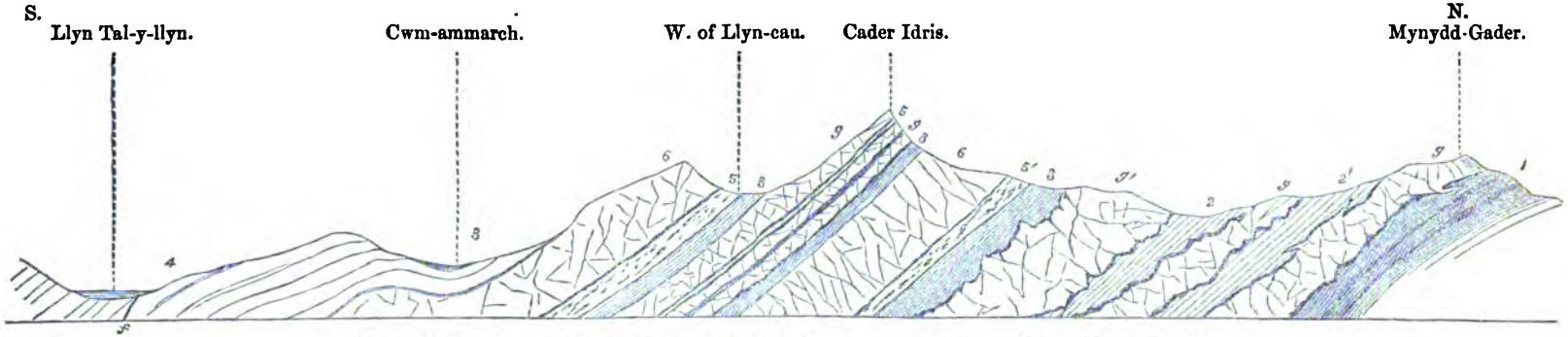
SECTION FROM TYRAU-MAWR TO THE ESTUARY OF THE MAWDDACH LOOKING EASTERLY.



1. Lingula flags and Tremadoc slates.
2. Arenig slates.
3. Stratified volcanic ashes of Arenig series.
4. Greenstone, intrusive and branching.
5. Felspathic porphyry, intrusive.
6. Felspathic porphyry.

Fig. 7.

SECTION FROM LLYN TAL-Y-LLYN ACROSS CADER IDRIS TO MYNYDD-GADER.



1. Lingula flags.
2. Tremadoc slates.
3. Arenig beds.
4. Llandeilo and Bala beds.
5. Stratified volcanic ashes of Arenig series.
6. Felspathic porphyry.
g. Greenstones.

Cader Idris.—If we examine the section on both sides of the above-mentioned fault* we shall find that in spite of intrusive rocks the masses nearly assume the general order shown in the diagram, Fig. 6, across Tyrau-mawr to the estuary of the Mawddach on a scale of two inches to a mile, while Fig. 7 shows the arrangement of the strata on a north and south line between Mynydd Gader, the peak of Cader Idris, and the west end of Tal-y-llyn.

On the north-west are the black slates of an upper part of the Lingula flags No. 1 intruded upon by, and partly dipping under, the greenstone of Mynydd-Gader. These are succeeded on the south side of Mynydd-Gader by the altered Tremadoc slates No. 2, which as already described (p. 30), and as shown in this section, are much interpenetrated by irregular masses of greenstone marked *g*. South of one of these masses the Arenig slates, No. 2 (Lower Llandeilo of Murchison), come on, and other dark blue slates of the same sub-formation are interstratified with the igneous series on Cader Idris as far south as Llyn Cau, and probably also lie on the highest porphyry in Cwm-ammarch. One of these below the porphyretic ash 5′ is from 80 to 200 feet thick, and is very constant all along the strike of the mountain. Above these Arenig beds we pass into the equivalents of the true Llandeilo and Bala beds, No. 4. Interstratified with these Arenig slates and the porphyries are beds of felspathic ashes which on Cader Idris are of comparatively inconsiderable thickness, but thicken in a remarkable manner as we proceed north-east to the region of the Arans. The ashy bed marked 5′ is of a highly porphyritic character and very hard. The felspathic porphyries No. 6 dip with the ordinary strata as regularly as the interstratified ashes, and seem to behave like great masses of interbedded lavas. That which forms so much of the north front of Cader Idris is about 1,000 feet in thickness, and the porphyry by Llyn Cau is nearly as much.

East of the Tyrau-mawr fault the porphyry No. 6, Fig. 6, lies with great regularity on a bed of felspathic ashes, which here strikes east and west beneath the northern cliffs of Cader Idris. These ashy beds are there about 100 feet thick.

The section No. 1, Pl. 28, which crosses Cader Idris and the Cambrian rocks of Llawllech from south-east to north-west shows, with minor variations, the same general arrangement of the rock-masses, as follows:—

In ascending order where crossed by this section, there are on the north-west first the Cambrian grits overlaid by a hundred feet or so of Menevian beds *m*, next the Lingula flags *l*, pierced by dykes and masses of greenstone *g*, and a mass of felspathic porphyry *F′* near Llyn-yr-wylfa, next Lingula flags *l′*, more intrusive porphyry *F*, which is succeeded between the Towyn road and the neighbourhood of Llyn-y-Gader by the great mass of problematical vesicular and sometimes calcareous rock, which is in places almost ashy looking (*see* pp. 31, 32). This is succeeded in ascending order by about 100 feet of Arenig slates *a*, overlaid by 100 feet of hard porphyritic ash *f* on which lies the great felspar porphyry mass *f* in which Llyn-y-Gader lies. Above this lie about 200 or 300 feet of Arenig slaty beds *a*, which are overlaid by a mass of greenstone *g* of about the same thickness, which here seems to be regularly interbedded but yet cannot with certainty be classed as a bed of lava seeing that it branches into two lines about a mile and a half further west on the northern slopes of Rhiw-gyriedydd, and on the north cliff of Cader Idris it has altered the Arenig slates both below and above it into a species of porcelanite. These overlying blue slates are about 60 or 70 feet in thickness, and are followed by 100 feet of hard porphyrytic felspathic ash *f′*; then by 20 or 30 feet of blue slate, on which rests a thick mass of vesicular and largely botryoidal greenstone *g* which forms the summit of Cader Idris. On the surface the vesicles are often empty, but in the body of the rock they are filled either with quartz or carbonate of lime, and sometimes with both, as if one had been partly removed and replaced by the other. The kernels are frequently coated with chlorite. The rock is about 500 feet thick, and forming the summit of Cader Idris, stretches down the south side of the mountain, forming the dark and broken mounds that roughen the slopes above Llyn Cau. The slate in contact with

* *See* the 1-inch map west of the C. of Cader Idris.

it is altered, being hard and porcelanic, and towards its western end it seems diagonally to cut across the strike of the slates that overlie the beds of ash on which this mass of greenstone rests at Cader Idris. On the northern cliff of Cader Idris, overlooking the Llyn-y-Gader, all these traps and slates may be seen bending along the face of the crag, and a bold climber may descend in the gullies, and walking along the ledges mark the effect of the greenstones on the associated slates.

The bottom of Llyn Cau, and the ground further east and west, is occupied by about 900 feet of blue Arenig slate *a'*, resting on greenstone. The slate is sparingly intermingled with thin bands of felspathic ashes, and sometimes the true slaty matrix contains small detached felspar crystals, entire or fragmentary. On the south side of the lake, resting on this slate, there again occurs a bed of felspathic ashes succeeded by a mass of felspar porphyry about 1,000 feet thick. It is sometimes rudely columnar, and has been described by Mr. Selwyn as a "grey and brown slaggy felspar trap, often porphyritic, with small crystals "of glassy felspar."* Its general character resembles that on the north slope of Cader Idris.

This section, taken together with Fig. 8, p. 39, might lead to the conclusion that these great bands of porphyry are essentially distinct, and that following as they do the southerly pitch of the strata, they represent two sets of enormously thick lava beds that flowed abroad on the muddy or ashy sea bottoms of the time, being separated by a long period represented by the accumulation of more than 2,000 feet of intervening stratified and igneous rocks. There is, however, this difficulty in the case, for interbedded as they appear, they seem to break across the strike and unite on the west at Twll-yr-ogof, and on the east by the brook that runs from Llyn Cau in the direction of Minffordd, thus at both ends cutting out the stratified rocks that separate them in the intervening space. *See* Index, Map, and quarter sheet 59 N.E.

It is a striking fact that, excepting the ashes, most of the igneous rocks from the Mawddach to Tal-y-llyn were not volcanic products thrown out upon the surface at the time of the formation of the slaty beds amid which they lie. However regular their dip, they mostly seem to be intrusive. Of the 4,000 feet of igneous rocks that dip southerly from the base of the Llyn-y-gader trap, not more than about 400 feet of ashes were contemporaneously formed with the slates with which they are interbedded. Though the ground is somewhat obscured by peat and heath, it is difficult to imagine the broad trappy mass of Mynydd Pennant with its continuation east to Llyn Cau to have been the result of simple contortion of the mass of country that contains the felspathic porphyry of Cader Idris and Cyfrwy, though there is a possibility of constructing a forced diagram that would explain the difficulty on that hypothesis. On the whole this does not seem so likely as the view that perhaps the western part of the Cader Idris porphyry towards Gallt-y-llyn has been injected more or less between the beds, and like the greenstones has since been disturbed by those later forces that threw into great curves the whole of the rocks of the country.

* For an explanation of the term slaggy, as here used, *see* p. 154.

In no part of this country can a clearer idea be obtained of the nature of its rocks and of their order of superposition than on the space that lies between the ridge of Mynydd-gader and the range of Cader Idris, for there slates, ashes, and felspathic porphyries lie in regular order, unbroken by faults and uncomplicated by contortion. As it is typical of the whole area between Cader Idris, the Arans, and Arenig, I shall, with the help of diagram 6, 7, and 8, attempt to explain its details.

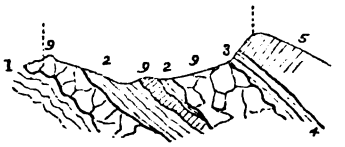
South of Dolgelli the Lingula flags are much disturbed and broken into by intrusions of igneous rocks. One of these forms the ridge of Mynydd Gader, as shown at *g'* in diagram No. 7. This mass, like others in its neighbourhood, is intrusive, the melted matter having been forced more or less between the planes of stratification, and here and there thrusting short veins in among the strata. On the north side of Mynydd Gader the Lingula flags No. 1 pass under the greenstone, and partly consist of black carbonaceous shale, once mistaken for and fruitlessly mined as plumbago. Above the rock of Mynydd Gader lie the Tremadoc slates No. 2, intersected by greenstones, one of which *g'* has been described in pp. 31 and 32. The Tremadoc slates from end to end of this wild upland valley are generally hard and porcelanic and break with a flinty fracture, the effect of the injection of melted matter all through the body of the rock at a time when the whole lay deep beneath the surface. Now, when upheaved and denuded, these greenstones vary from a few yards to about a mile in length, and so intimately are they intermingled with the Tremadoc Slates that in mapping it is difficult to separate them, and quite impossible to represent them accurately on the 1-inch scale of map, for the smaller bands are often only a few feet thick. The larger ones are, however, sometimes several hundreds of feet in thickness, and all of them are apt to run between the beds in or nearly in the line of strike, a circumstance that may lead to the suspicion that some of them may be the result of the actual fusion of layers of the strata amid which they lie. *See* Fig. 4, p. 31.

In this upland valley the Arenig slates (3, Fig. 8) are well seen all along the base of the great cliff of the range of Cader Idris on its northern face. They are separated from the underlying Tremadoc slates by broad masses of intrusive igneous rocks 9, and are overlaid by a band of felspathic ash 4 as shown in the diagram. It is in these Arenig beds that a well known band of pisolitic iron ore occurs, which has been frequently worked and abandoned. It may be traced at intervals beneath the north and north-western face of the mountain as far as Ffordd-ddu, and on or near the same general horizon it occurs north of Geugraig and on the ground west of the Cross Foxes.

Rather more than a mile east of the summit of Cader Idris the section between Mynydd-Moel and Mynydd-Gader shows the same general arrangement of the strata as shown in the following Fig.:—

Fig. 8.

SECTION BETWEEN MYNYDD-MOEL AND MYNYDD-GADER.



1. Black slates of the Upper Lingula flags.
2. Tremadoc slates, mostly altered.
3. Arenig slates.
4. Felspathic ashes.
5. Felspathic interbedded porphyry, *g*, greenstones.

Enough has now been said to show the geological structure of the range of Cader Idris and the adjoining ground, and I have given it in detail not only because it is a region much visited, but also that in spite of all its complications it may be considered, with regard both to its common statified and its igneous rocks, to present a sort of type of much of the mountain land of North Wales as far as the range of the Moelwyns.

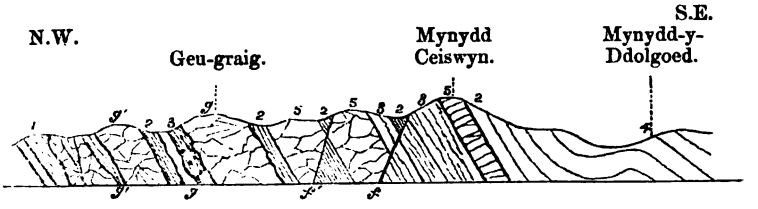
On the upper slopes of Cader itself the main geological features on which the landscape depends are clear and simple. A vast mass of felspathic porphyry forms the precipitous front of the lofty cliff that 7 miles in length ranges from Craig-cwm-llw on the west to Mynydd Moel and Geu-Graig on the east, and the strike of this rock with its underlying and overlying strata of slates and ashes all dipping south is easily visible even to the inexperienced eye in the long lines of varied colour that run along the face of the cliff east and west of the peak of Cader Idris. On the northern slopes the felspathic porphyry is slightly hornblendic and jointed, especially on Mynydd-Mawr where the joints have all the regularity that they sometimes assume in granitic masses. Beautiful symmetrical columns give a special character to the cliffs of Cyfrwy and strew the slopes below. They are often used for gate-posts. The broken ground facing Mynydd-Mawr west of Llyn-y-Gader is strewn and piled with blocks that have fallen from the cliff, some of which in size may almost be compared to small houses. These lie in large irregular heaps, and with the moraine-like mounds nearer the cliff probably owe their arrangement to a time when the glacier-ice packed of old between the cliffs of Cader Idris and Mynydd-Gader had began to waste away, and landslips and other débris from above slipped down the icy slopes. Now in the minor hollows the tinkling sound of flowing water is often heard beneath the stones, and cold springs, clear and full, break here and there from underneath the débris. The underground waters have partly carried away the smaller stones and earthy particles, and the irregularity of the surface has thereby been increased.

One additional diagram may suffice to explain the structure of the ground near Cader Idris, where the strike of the strata and associated igneous rocks

changes to north-east. It represents the general arrangement of the rocks on a N N.W. line, between the south-western end of Mynydd-y-Ddolgoed, about 4 miles S.S.E. of Dolgelli, to a point about 2 miles S.S.E. of the town in the brook near the north-eastern angle of the greenstone of Mynydd-Gader, and is given to show the repetition of the igneous rocks by faults, which, as they range northerly, produce a great effect on the physical geography of the country of the Arans and Arenigs.

Fig. 9.

SECTION FROM MYNYDD-Y-DDOLGOED ACROSS MYNYDD CEISWYN TO GEU-GRAIG NEAR DOLGELLI.



1. Tremadoc slates.
2. Arenig slates.
3. Felspathic ashes.
4. Llandeilo and Bala beds.
5. Felspathic porphyry.
f. Faults.
g. Greenstone.

In this diagram the strata No. 1 represents the Tremadoc slates, No. 2 the Arenig slates partly in among the greenstones *g*, and partly overlying the felspathic porphyries and ashes, Nos. 3 and 5, which are repeated by two faults *f*. The Arenig beds above the Mynydd Ceiswyn porphyry pass upwards into the slaty beds of the Bala series. There is no essential difference between the rocks on this line and those farther west. The felspar porphyry, No. 5, is perhaps less massive looking, being less crystalline than the columnar and jointed masses of Cyfrwy and Mynydd-Moel, and specks of hornblende are more rare. The same greenstone *g*, and also marked *g'*, that lies in front of the great cliff of Cader Idris, runs northward across the range of this section and seems to branch into three parts at Pen-y-bwlch-goch at its northern end. It is overlaid by a band of slates and pisolitic ironstone from 70 to 100 feet thick. These slates have been in places baked into porcelainite where they touch the greenstone. On their eastern side there runs a long narrow line of greenstone, above which is a highly porphyritic blue band of ashes of about equal thickness and identical with that which underlies the porphyry of Cader Idris and Mynydd-Moel. Though porphyritic it is readily distinguishable from a genuine crystalline porphyry, for its crystals look not as if separated from the matrix during the process of cooling, but rather as if they had been showered out along with and mechanically embedded in an ashy paste. They are, besides, often broken, and pebble-like fragments and slaty flakes occur in the enveloping spathose matter. On this, in ascending order, lies the greenstone of Geu-graig, in places forming a grand cliff that faces the north-west, and which in the south-western part of its course branches into two lines which include a band of altered slate. This greenstone has a kind of rubbly look, somewhat resembling that which forms the crest of Cader Idris and the still larger mass immediately north of Llyn-y-Gader (marked *g'* in Fig. 7, p. 35). On Geu-graig this rubbly character conveys the impression that in cooling, the mass had arranged itself in large spheroids, which occasionally show a tendency to angularity at the sides as if attempting to assume a columnar structure.

Beyond the north end of the Geu-graig greenstone north-west of Gwern-graig, the slaty band with pisolitic ironstone is traceable for about half a mile, with a compact blue felspathic ash below, while overlying it there is a coarse brecciated felspathic ash, some of the fragments in which are more than an inch in diameter. The ashes are of much the same thickness as in the previously described sections. The felspathic trap is about 1,800 feet thick, only a little thicker than the Llyn-y-Gader division of the same rock on Cader Idris.

Of the two faults shown in the diagram, the more westerly, which a little further south passes through Llyn Trigraienyn, may be considered a continuation of the great Bala fault, and the other, though apparently of nearly equal magnitude, is lost on the south-west among the slates between Mynydd-y-fronfraith and Afon Llefeni. On the north-east it perhaps ends against the small north-west dislocation that lies between Waun-oer and Cribin-fawr.*

North-east of Geu-graig for several square miles the structure of the country is exceedingly complicated by faults, greenstones, and contortion of the rocks; the whole being rendered yet more obscure by the deep glacial drift that covers many of the valleys and slopes round Caerynwch and the Cross Foxes.†

The Geu-graig greenstone spreads out towards the north, because of the gradual decrease of its inclination. It has been stated that a band of slate overlies it (diagram Fig. 9). The great Bala fault, it is inferred, here passes across the turnpike roads underneath the drift on its passage to the valley of Tal-y-llyn. At Geu-graig and Hafod-oer, a little further to the north and east, the sections are, in fact, nearly identical, and consist in descending order of felspar porphyry, slate, greenstone, and true felspathic ashes.

Within half a mile north-east of Hafod-oer the greenstone is affected by two small dislocations. These coalesce by Ty'n-rhos and resolve themselves into one fault, which passes in one direction across Pen-bwlch-coch from east to west, and throws down the ashes and the slates with iron ore against irregularly intrusive masses of greenstone. These greenstones, with others of their class in Merionethshire and Caernarvonshire, though manifestly injected, are, like the bedded felspathic rocks, invariably affected by the contortions of the rocks and the faults of the district, proving the injection of the greenstone before these disturbances took place.

The passage of masses of greenstone from one stratigraphical horizon to another is well shown in the triangular space that is enclosed between the Bala, Dolgelli, and Pen-bwlch-coch faults.‡ Immediately north of the last, one of the greenstone masses passes somewhat obliquely to the strike, from the slaty beds below entirely across the ashes, and intrudes itself into the overlying felspar porphyry, which is here thrown down to the west by the Bala fault, and forms a long narrow band between the neighbourhood of the sixth milestone on the Bala road and that part of Foel-y-seudian which lies 3½ miles east of Dolgelli.§ This line of felspathic porphyry is the undoubted equivalent of the great mass that forms the cliff of Cader Idris and the western slope of Aran Mowddy. It is therefore also the equivalent of the felspathic lava beds of Y-Wenallt, Careg Aderyn, and Penmaen, but the downward throw of the fault cannot be nearly so great as that which is shown in section No. 3, Pl. 28, between Aran Mowddwy and Careg Aderyn, for immediately east of the fault the strata consists of Tremadoc slates, Arenig beds, and the overlying felspathic ashes.

Another large and irregularly branching mass of greenstone, penetrating the Lingula flags, lies between Tyddyn Mawr‖ and Pen-ar-Wnion,¶ and three times in its windings it abuts on the Dolgelli fault, which here, by a north-western downthrow, again brings in the great mass of ashy beds of Moel Offrwm and its neighbourhood.**

Near Dinas Mowddwy a north-west fault passes up the valley of Afon Geryst to a place called Esgeiriau, where it joins the Bala fault near the sixth milestone previously mentioned.†† The rocks dip south-easterly, and are thrown

* One mile and a half south of the fifth milestone on the road from Dolgelli to Dinas Mowddy.

† East of Dolgelli from 2 to 3 miles.

‡ The Dolgelli fault is supposed to bound the greenstone of Llwyn and to extend to the sixth milestone on the Bala road. It there joins a great branch of the Bala fault which runs north by Y-Dduallt and Moel-llyfn-nant to the Bala and Ffestiniog road near Tai-hirion. The Bala fault runs from the sea near Aber Dysynni to the edge of the New Red Sandstone near Hope, a length of about 60 miles.

§ Maps 59 N.E. and 75 S.E.

‖ One mile and a half E.S.E. from Dolgelli.

¶ Above the Bala road 4½ miles north-east of Dolgelli.

** Two miles and a half N.N.E. of Dolgelli.

†† Maps 59 N.E., 60 N.W., 74 S.W., and 75 S.E.

down on the south-west from 2,000 to 3,000 feet. West of the Dinas Mowddwy fault, near Esgeiriau, the Tremadoc slates and Arenig beds dip south-east at angles of 35° and 40°. Above them lie the ashes, and these are succeeded by the same felspar porphyry that forms the ridge of Cader Idris and the Arans, on which rests the dark blue slates that run all along the strike between the south slopes of Cader Idris and the eastern flanks of the Arans. The same porphyry also forms the centre of an anticlinal axis on the turnpike road, about 2 miles north-west of Dinas Mowddwy (Fig. 10, p. 45). Its eastern continuation is cut off by the fault, and the slate having been removed by denudation from the crown of the arch, the igneous rock is exposed in the valley of Afon Geryst.

Something remains to be said respecting the grit that divides the Tremadoc slates from the Arenig beds. As mapped from Llanegryn to the north by Mr. Ward and Mr. Hebert, it can only be traced by the help of fragments on the hill side, till we approach the slopes on either side of the stream that flows through Cwm-llwyd to Llwyn-gwril, where it is seen *in place* owing to the better exposure of the rocks. North of this it is lost for about two miles in a drift covered area, but again appears for a space south of Goleu-wen and a little west of a line of greenstone, where I found the grit to be accompanied by what may be a bed of coarse volcanic conglomerate. A little further north a probable fault runs south from Tyddyn Jeffrey,* and on the east side of this fault Mr. Ward and Mr Hebert found it in the wooded slope further east.

From this point all along the broken hills between the Mawddach, Cader Idris, and Geu-graig it is quite unknown. This may be partly accounted for by the circumstance that so much of the country is covered by glacial drifts and numerous thick woods, and also that the ordinary stratigraphical geology of the country is, so to say, troubled by the presence of ever recurring irregular masses of greenstone. However this may be the grit is not recovered till passing into the district of the Quarter Sheet, 75 S.E., it—as mapped by Messrs. Ward and Hebert—appears south of the great Bala fault, repeated several times by smaller faults, south and east of Pen-ar-Wnion, about four and a half miles from Dolgelli on the Bala road. The evidence here is somewhat fragmentary, but it is seen by the brook about half a mile south of Esgeiriau, where it is cut off on the east by a north and south fault, to be again taken up about 30 or 40 feet below the ash of Brynmawr, beyond which on the west flank of Aran Mowddwy and Aran Benllyn it is much obscured by debris till it again appears in force beneath the ash west of Moel-phenic and Moel-ddu, and disappears against the great Bala fault near Cwm-yr-onen, about two miles south of Llanuwchllyn.

* About a mile and a quarter S.W. of Capel Arthog.

[illegible]

THE RANGE OF THE [illegible]—THE [illegible] PLATE

General Dip—[illegible] rocks and of the [illegible] beds that on the [illegible] dip, with few exceptions, [illegible] from 40° to [illegible]

Between [illegible] position they [illegible] base of which is [illegible] feet thick, and [illegible] the upper Lingula flags well seen in the hill [illegible] looking [illegible] of grey Tremadoc slates [illegible] base of the Arans [illegible] thickness [illegible]

These ashes [illegible] ashy strata [illegible] Idris. In general terms they may be [illegible] a fel-pathic base, in which there [illegible] lenticular [illegible] containing fragments [illegible] size of a [illegible] conglomerate is well seen [illegible] did not, about half a mile west of the [illegible] The rounded fragments often look as if [illegible] these and the angular pieces are for the most part composed of felspathic porphyry containing distinct crystals of glassy felspar. The weathered surfaces of the rock best show its true character, and it then becomes apparent that much of it is composed of aggregations of broken crystals of felspar, confusedly imbedded in a hardened felspathic paste. Sometimes this structure entirely disappears in a freshly-fractured surface, but frequently even then it is apparent. This is alike characteristic of the porphyritic ashes of the Arans and Cader Idris, and may be accounted for on the supposition that broken crystals were showered out with the more finely comminuted felspathic dust, which is the chief constituent of the matrix of the rock. Occasional thin slaty beds mingle with the ashes. The whole mass dips E.S.E. at angles of from 60° to 80°, and attains a thickness of about 3,300 feet. Further north the ashes thin rapidly away, for at the end of the Aran range by Moel-ddu their thickness has decreased to about 1,000 feet. The inclination of the beds is also much less, in places not exceeding 30°. N. 2., fig. 12, p. 49.

The felspathic porphyries which overlie the ashes and volcanic conglomerates, include two long thin bands of dark blue Arenig slate, the ends of which nearly meet less than a quarter of a mile

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* *See also* 6-inch section, Sheet 29.

north-west of the top of Aran Mowddwy.* The thickness of the porphyry where crossed by the section (No. 3, Pl. 28), is from 1,100 to 1,200 feet. It much resembles that of Cader Idris, the base being felspathic and containing crystals of felspar. It is somewhat harsh to the touch, sometimes columnar or largely jointed, and by the occasional sparing development of hornblende, it may sometimes be said to assume the character of a hornblendic felspar porphyry, or of a very felspathic greenstone. A band of slate about 100 feet thick separates the porphyry from the ashes. This slate is undurated at its junction with the porphyritic lava as if by heat.

It is clear that the range of the porphyries from end to end of the Arans is not to be looked on as one mighty lava-flow, but rather as the result of successive outpourings from a volcanic vent, some of the intervals being marked by slaty interstratifications. The ashy beds both below and above the porphyries must have been blown from the same vent or vents, and are doubtless the result of many eruptions.

Like the underlying ashes, northward toward Moel-ddu, the porphyry thins away to about 800 feet in thickness.

The upper ashy beds that form the top of Aran Mowddwy are well bedded and very hard and felspathic, and stretch all down the steep eastern slope of Craig-lyn-Dyfi, close to the western shore of which they dip beneath the slates at an angle of about 60°. At Aran Mowddwy the ashes are about 550 feet thick, and about three miles further south they thin entirely away on the southern slope of Craig Cowarch. Northward they pass on to the Bala fault against which they abut about half a mile east of Llanuwchlyn, thinning away in their northward progress till on Moel-ddu (6-inch sections, sheet 37), they are not more than 350 feet in thickness, and near Llanuwchllyn they are thinner still, Fig. 12.

South-west of Aran Mowddwy in the neighbourhood of Afon-Cwm-ochr numerous greenstone bands have been intruded, among the Lingula and Tremadoc beds and the ashes; but north-east of the felspathic trap of Y-Foel-ddu these are comparatively rare.

West of Aran Mowddwy this igneous boss touches the ashy beds of Y-Gadfa, and stretches north towards the lower part of Cwm-y-dolau. It thus passes across the Lingula beds, nearly from top to bottom, in a broad mass, the greatest length of which runs nearly at right angles to the strike of the Lingula flags and Tremadoc slates. Lithologically, it resembles the felspathic traps of the Arans and Cader Idris, being for the most part a compact blue rock, occasionally vesicular, weathering white or pale yellow. Its form shows its intrusive character, and wherever the strata are seen in contact with it, they are bleached and porcelanic for a few inches from the line of junction. The strong resemblance which this felsitic mass bears to the felspathic porphyries of the Arans, and in material to the conglomeratic and other ashy beds of the district seems to favour the idea that it may be one of the under-

* Possibly they may be the same band, the continuity of which is interrupted by a fault or faults. It is not crossed by the section.

ground necks or centres of eruption from the crater of which the lavas and ashes of the district were ejected.

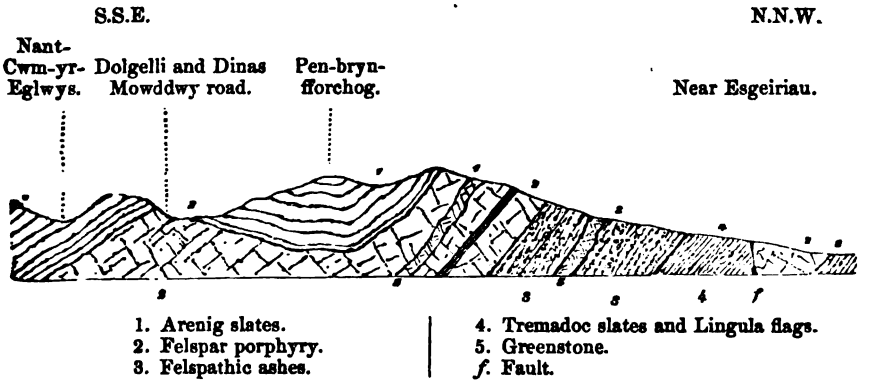
Taken as a whole, the Aran section is the simplest of this part of the geological series in Wales, for the Lingula flags, Tremadoc and Arenig slates, and volcanic interbedded series maintain a steady unbroken easterly dip, and from thence with a few minor anticlinal rolls the lower strata are continued up into the overlying Bala beds, which pass beneath the Upper Silurian strata. In its lower members it is more easily made out than the corresponding section between the Mawddach and Cader Idris,* owing to the comparative absence of masses of *intrusive* felspathic porphyry and of injected greenstones, which, nearer Dolgelli, often induce such excessive complication in the details of the Lingula flags and Tremadoc slates, and the igneous series above them; for, besides being of all shapes and sizes, and occurring at all horizons between the Cambrian rocks and the base of the Llandeilo beds, their presence being as it were accidental, it becomes no easy matter to unravel in the field the geological intricacies of a mountainous country where felspathic porphyries, ashes, and greenstones are often externally so much alike, that the most practised eye can scarce distinguish them before the application of the hammer. But, notwithstanding these accidental complications near Dolgelli, the foregoing descriptions make it evident that between the top of the Cambrian rocks north of the Mawddach and the Bala and Llandeilo beds that rest on the Cader Idris range, the general section perfectly resembles that of Aran Mowddwy, as low as where in the latter the Lingula beds are cut off by the Bala fault.

Before closing the account of this part of Merionethshire a little remains to be said respecting the extension of the felspathic rocks to the Dolgelli road about two miles from Dinas Mowddwy.

South of the Arans between Nant-Cwm-yr-Eglwys† and the neighbourhood of Esgeiriau the rocks lie nearly as shown in the following diagram.

Fig. 10.

SECTION NORTH-WEST OF DINAS MOWDDWY.



* Section 26, lines 2 and 3, and Pl. 28, No. 1.

† One mile and a half W.N.W. of Dinas Mowddwy.

In descending order No. 1 at Nant-cwm-yr-Eglwys and Pen-bryn-fforchog represents the upper part of the Arenig slates passing into the Bala beds, No. 2 the underlying felspar porphyry curving in anticlinal and synclinal axes between Nant-cwm-yr-Eglwys and the north-western slopes of Pen-bryn-fforchog. Beneath the porphyry lie the felspathic ashes, No. 3; beneath which lie the Tremadoc slates and Lingula flags, No. 4, which, long before we reach their base are cut off by the Bala fault *f*, again bringing in the felspar porphyry and ashes (Nos. 2 and 3) by a downthrow on the north-west of about 7,000 feet. Greenstones (No. 5), dipping irregularly with the other rocks, pierce them in two places.

North-east of the Dinas Mowddwy fault the rocks are for about a mile slightly complicated by greenstones and several minor dislocations.

The Bala Fault.—I shall now notice some of the effects produced by the great Bala fault on the area between the Aran range and the Bala and Dolgelli road.

The effect of this fault further south-west has already been shown in diagram No. 10, where, between Mynydd Ceiswyn and Geu-graig, the felspathic traps have been thrown down on the north-west probably about 1,000 feet. In that neighbourhood, a little north of the turnpike gate, the fault passes into the ashy series, and being a downthrow on the north-west, the same beds are repeated, which, if the mapping be correct, sufficiently accounts for the colouring on the map of the broad drift-covered tract presumed to be to a great extent occupied by ash in the country east and west of the inn called the Cross Foxes.

Still further north-east, it has been shown (Fig. 10), that the felspathic porphyry, 2, and ashes, 3, of Pen-bryn-fforchog have been thrown against the Lingula beds, 4, by the fault *f*, and that the amount of this throw is probably near 6,000 feet. When followed along its strike, this porphyry leads directly to that of Wenallt, Careg-Aderyn, and Penmaen.*

These hills form a steep cliffy slope along the Bala road, and the Bala fault runs at their base as far as Pant-gwyn,† beyond which the line between the igneous rocks and the *overlying* black slates and shales strikes nearly due north along the eastern flank of Arenig. From Pant-gwyn the fault passes into Bala lake, cutting off the whole of the rocks of the Aran range near Llanuwchllyn in their passage north.

At the point crossed by the section (Pl. 28, No. 3),‡ the unbroken dip of the rocks between Careg-Aderyn and Aran Mowddwy, makes it practicable very nearly to estimate the amount of downthrow by which the felstones and ashes of Aran Mowddwy have been brought to the level of Careg-Aderyn.

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* Map 74 S.W., west of the Bala road.

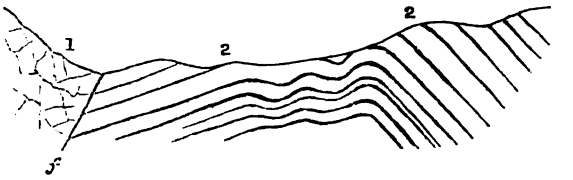
† Two miles and a half south-west of Llanuwchllyn, Map 74 S.W.

‡ *See also* 6-inch Sections, Sheet 29, lines 2 and 3.

Assuming what is easily proved, that the felstone of Careg-Aderyn is the equivalent of that of Aran Mowddwy, the following are the necessary steps in the argument:—

1st. Eastward of Careg-Aderyn the rocks dip steadily east at high angles showing no symptom of an anticlinal axis, excepting at one place near the Bala fault in the bed of the brook by the old copper mine opposite Drws-y-nant-isaf, where the lower strata of the Lingula flags in a short anticlinal curve dip towards the fault at an angle of about 20°, the result probably of the forcible

Fig. 11.



1. Felspathic porphyry.
2. Lower Lingula flags.
f. Fault.

bending down of part of the beds against the fracture by the downward slip of the vast mass of rocks on the west, or if it be preferred, by the upward crush of the great block of country on the east. The Aran Mowddwy felstone porphyry is therefore not brought to Careg-Aderyn by a roll of the strata.

2nd. It is evident by this repetition that the Aran Mowddwy rocks once extended, before their disturbance, in unbroken continuity in that direction.

3rd. The beds between the fault and Aran Mowddwy seemingly resting conformably on each other, and they have all been raised into their present inclined position together.

4th. If we restore the continuation of the separate beds between the fault and Aran Mowddwy, and make an allowance for the thinning out of felstone and ashes to the north-west; and if we prolong the fault upwards at its assumed angle till the lines meet, then if the porphyry in the valley by Careg-Aderyn correspond to that of Aran Mowddwy, the downthrow on the north-west from * to * (*see* Pl. 28, No. 3) must be from 10,000 to 11,000 feet. The angle at which the fault is drawn is hypothetical, and this, of course, may modify the amount of throw. Still, were we to reduce the inclination of the fault to the lowest possible amount, viz., to the average slope of the ground from the valley to the summit of Aran Mowddwy, it would still give a displacement of strata of at least 11,000 feet. It is by no means necessary to suppose that the whole of this enormous displacement took place at once, or even during any one of those sections of geological time that for convenience we name periods, for the aggregate

amount may be the result of many slips, extending through several geological epochs. However this may be, it is nearly certain that with sufficient denudation a very little additional downthrow would have exposed in the valley the uppermost Menevian beds and the Cambrian grit, since about 6,000 feet of Lingula, Tremadoc, and Arenig slates are exposed between the ashes and the valley of the Wnion. Towards Bala Lake the throw becomes gradually reduced to about 5,000 or 6,000 feet. The inclination of the strata decreases, and only about 2,500 feet of the flaggy strata, and 2,200 feet of ashes and porphyry between Pant-gwyn and Pandy* abut on the dark slaty shales that rest on the igneous rocks of the Arenig and Penmaen range, which shales are the equivalents of the beds that overlie the felstone of Aran Mowddwy. This reduction of the throw from 11,000 to 5,000 feet is proved by comparing the section in Plate No. 28 with the west end of the following diagram, Fig. 12, the ground which the lines of section cross being little more than 3 miles apart.

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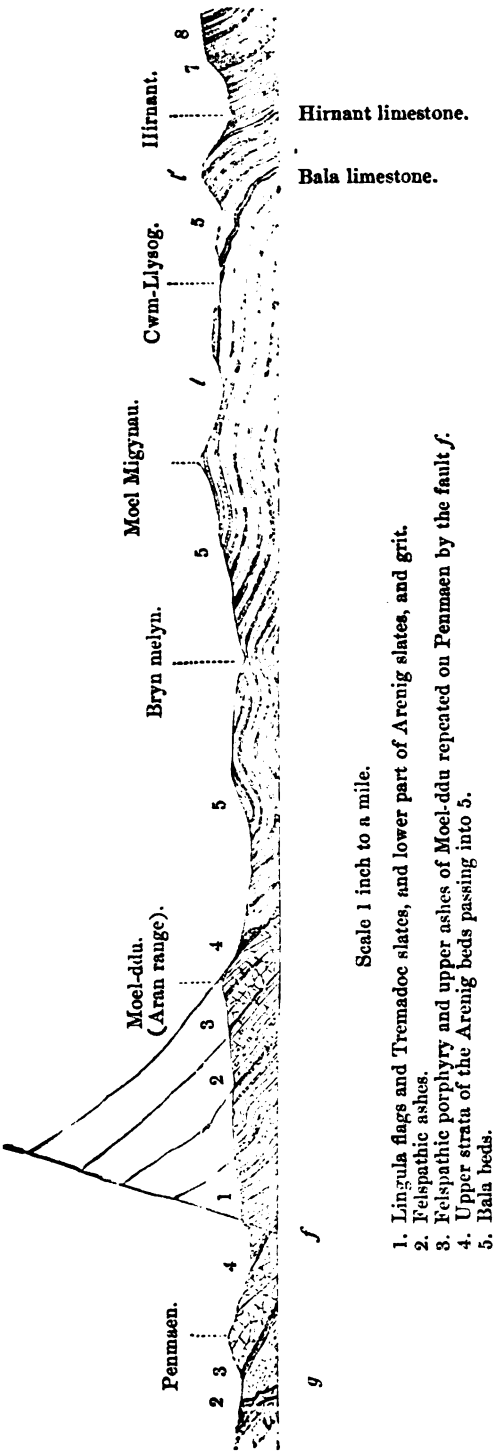
* About half a mile south-west of Llanuwchllyn.

Fig. 12.

SECTION ACROSS PENMAEN AND MOEL-DDU AT THE NORTH END OF THE ARAN RANGE.


Penmaen.
Moel-ddu. (Aran range).
Bryn melyn.
Moel Migynau.
Cwm-Llysog.
Hirnant.
Hirnant limestone.
Bala limestone.
Scale 1 inch to a mile.
1. Lingula flags and Tremadoc slates, and lower part of Arenig slates, and grit.
2. Felspathic ashes.
3. Felspathic porphyry and upper ashes of Moel-ddu repeated on Penmaen by the fault f.
4. Upper strata of the Arenig beds passing into 5.
5. Bala beds.
l. Bala limestone.
l'. Hirnant limestone in Bala beds.
7. Tarannon shale.
8. Denbighshire grits (Wenlock).
g. Greenstone.

CHAPTER VII.

Repetitions of the Rocks of the Aran Range by Faults and Curvatures of the Strata continued.—Greenstone of Rhobell-Fawr, &c.—Talcose Schists of Dol-y-Frwynog.—Copper and Gold Mines.

General Description.—A long straight valley through which the turnpike road and railway run, lies between Bala Lake and Dolgelli. It has been already stated that the range of hills that bounds it on the north-west results from the repetition of the hard felstones of the Arans by the fault described at the close of last chapter. Escaping from the immediate influence of the fault at Penmaen, this range suddenly trends straight north as far as Arenig, beyond which, the hills formed by the igneous rocks, become broken and spread by the effect of anticlinal and synclinal undulations over a wide extent of country. Near Drws-y-nant-isaf* on Careg-Aderyn and Penmaen, and northwards towards Arenig, the rock is a blueish grey felspathic porphyry, which breaks with a sharp fracture, like hornstone, and weathering pale yellow or white, often shows after the manner of some lavas a brecciated and slaggy or even scoriaceous structure, which, however, on a freshly fractured surface is generally indistinguishable. The same felspathic and calcareous ashes and conglomerates that underlie the felstones of the Arans rise from under its western edge.

A mass of *upper ashes* (so called because they lie above the felspar porphyry) commences about half a mile north-east of Penmaen, and gradually increasing in thickness, soon becomes, on the Arenigs, of very great importance. These are in position the general equivalents of the upper ashy beds of Aran Mowddwy.

North of Y-Foel-ddu and Penmaen and west of the eastern edge of the porphyry and upper ashes, the rocks lie in the form of an anticlinal and a synclinal curve both faulted. But for the faults, we should have in the main on the west, a simple synclinal curve of porphyritic rocks, underlying and enclosing an isolated basin of slaty shales between the porphyry of Careg-llysog and Y-Dduallt. The result of the faults that produced this arrangement of the rocks is, that in this part of Merionethshire there are three hilly ranges trending from south to north, first, that of the Arans; second, that of Penmaen and the Arenigs, while a third marked range of hills, forms the heights that run between Craig-y-Benglog and the peak of Moel-llyfn-nant. The materials composing all of these ranges, till disturbed, faulted, and laid bare and separated by denudation, originally consisted of one broad spreading mass of volcanic accumulations, which, indeed, also spread far beyond the area now under immediate review. Beneath the western range

* Ten miles and a half from Bala on the Dolgelli road.

of Craig-y-Benglog the ashes crop out a third time, overlying the Tremadoc slates and Lingula flags, which, with some broad undulations of the strata, spread from four to five miles westward towards the edge of the central boss of Cambrian grits.

Felspathic rocks and Arenig beds north and west of the Bala and Dolgelli road.

Westward of Drws-y-Nant-isaf the felstone is in part more than a mile in width, being thrown over to the west in the anticlinal curve mentioned above, one side of which beyond Y-Wenallt and Y-Foel Ddu, is cut off by a fault that passes northward, and crosses the Bala and Ffestiniog road a little west of Tai-hirion, and from thence ranging still further north on the west side of Arenig-bach.* This anticlinal curve widens by degrees, and volcanic ashes and slates, cut up by numerous small faults (too close and insignificant to be traced on a one-inch map), form its centre.†

The disturbance of the rocks is here so excessive, that it becomes truly difficult to disentangle their intricacies, since, in addition to the irregular mixture of ordinary sediment and ashy matter, these are so interpenetrated by thin injections of greenstone that it is almost hopeless to attempt on a one-inch scale to separate the latter from the ashes that often assume their outward aspect.

Following the anticlinal line to the north by Drysgol, the porphyry again closes over the ashes and slates, and in the sharp bend the beds have snapped at Castell-carn-dochan,‡ and a narrow strip of upper ashes, let in between two faults, forms part of the ridge of Cerig-yr-eirch and the valley that runs from thence towards Dolhendre.§

North of Cerig-yr-eirch the felspathic lava occupies a rough and rocky tract of about 2½ miles in length by 1½ in width, comprising the hills of Bryn-brâs,‖ Craig-dol-fadr, Clogwyn-yr-Eglwys, and Ffridd-trawscoed. The rock-mass undulates in wavy contortions, whence its unusual breadth. On the east it is overlaid by the upper ashes, and on the north, south, and partly on the west it is bounded by faults. The south fault is one of those that cross the ridge of Cerig-yr-eirch. It is a downthrow on the south. The north fault passes about 2½ miles in a south-western direction from Moel-y-menyn.¶ The west fault passes from Y-Foel-ddu northward, and joins the Tai-hirion and Y-Dduallt fault on the east slope of Moel-llyfn-nant.** Entirely surrounded by these felspathic porphyries, there is a high tract of slaty country running southward from Clogwyn-yr-Eglwys. These strata belong chiefly, if not entirely, to the upper portion of the Arenig slates that, when unbroken by faults, rest on the igneous series of Arenig and the Arans. The whole area is about 4 miles in length. When its structure is analysed, it is obvious that the adjoining porphyries and slaty rocks between lie in the form of a synclinal curve. But for the two long north and south faults, that converge and meet on the east side of Moel-llyfn-nant, the porphyritic rocks on the east side of the slates would dip under them (as indeed they partly do on Cerig-yr-eirch), while the western porphyry that ranges north from Y-Dduallt would rise directly from underneath the slates were it not that the latter are on their west margin faulted against the porphyry. A section across the country from east to west, between Moel-y-graig and 'Rallt-llwyd, gives the following general arrangement of the rocks:—

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* Map 75 N.E. and S.E.

† Shown in the 6-inch sections, between Careg-Llyssog and Careg-Aderyn, in Sheet 19, Pl. 2, and between Careg-Llyssog and Penmaen, in Sheet 37, line 3.

‡ One mile and a half west of Llanuwchllyn.

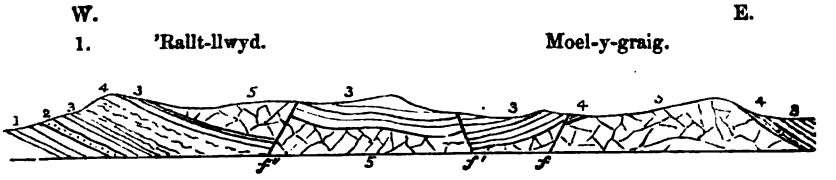
§ Dolhendre is a house lying 1⅓ miles W.N.W. of Llanuwchllyn.

‖ Two miles from Llanuwchllyn, a little north of west.

¶ Moel-y-menyn lies 1½ mile, S.S.E. from the top of Arenig.

** Moel-llyfn-nant is a trigonometrical station 1¾ miles south-west of Arenig, Map 75 S.E.

Fig. 13.



1. Tremadoc slates.
2. Arenig grit.
3. Arenig slates.
4. Felspathic ashes, lower and upper.
5. Felspathic porphyry.
f. Faults.

On the east of Moel-y-graig there lies, dipping east about 40°, an upper part of the Arenig slates, No. 3, under which the upper ashy beds, No. 4, crop out, lying on the interbedded felspathic porphyry No. 5, which rolls over in an anticlinal curve towards the fault *f* overlaid there by a fragment of the ash. On the opposite side of the fault the Arenig slates are thrown in in a low synclinal curve, broken by a fault *f'*, which has produced a downthrow on the east. On the west of the curve Arenig beds rise against the porphyry, 5, and abut on it at the fault *f''*. Still further west, there is a thin band of slate, 3, beneath the porphyry and lying on felspathic ashes (4), which, in its turn, lies on Arenig slates, 3, at the base of which there is the grit so often mentioned, which here, as elsewhere, overlies the Tremadoc slates.

I have said that these porphyries are the general equivalents of that of the Arans. In structure they are the same. The very prominent hill called Y-Dduallt consists of felstone, of a slaggy aspect, blue or grey in colour, often porphyritic, sometimes rudely columnar, and bearing a general resemblance to the equivalent rocks of Careg-Aderyn, Penmaen, and Aran Mowddwy. It is about 1,200 feet in thickness, and dips easterly at angles of from 40° to 50.° Beneath it, in the usual position, are the felspathic, sometimes calcareous, and conglomeratic ashes, dipping east about 45° beneath the trap. As we approach their base, the angle decreases to 15° or 20°,* but these angles are much increased along the line of strike both north and south of this point.† In the area crossed by these sections the ash principally consists of a greenish grey felspathic base with felspar crystals, enclosing numerous irregularly rounded lumps of vesicular green and greenish grey trap, the vesicles being often filled with quartz and carbonate of lime. This general lithological character is frequent, not here alone, but in some of the ashes further south, and also on Aran Mowddwy, reminding the observer of those viscous masses shot from volcanoes that fall among accumulating ashes during periods of eruption. Being generally green, and forming a large part of the ashes, these are in places almost indistinguishable from the more rubbly descriptions of greenstone, such as occur on parts of Cader Idris and south of Y-Dduallt on Craig-y-Benglog, and as erupted matter they may, before ejection, have formed part of the melted matter now recognised as a kind of rubbly-looking greenstone rock.

The lower part of the ash between Y-Dduallt and Rhobell-fawr has a compact blue base, with embedded slaty flakes. In places it resembles some of the felspathic rocks that have been poured out as streams of lava, so much so, that in a hand specimen, or even *en masse* on the ground, the inexperienced observer might readily be deceived. The instructed eye, however, soon detects its bedded character; and, when walking along the strike of the country, the

* Where crossed by the 6-inch section, Sheet 19, line 2.
† Six-inch section, Sheet 37, line 3.

upper surfaces of thick strata are seen dipping eastward in frequent succession, thus—

Fig. 14.

Sometimes distinct crystals of felspar are sparsely scattered in the blue base; and again, broken crystals of the same mineral are often thickly set in it, giving a beautifully prophyritic aspect both to the weathered surface and to the freshly fractured stone.

As usual, various interstratifications of slate occur in the ashes. One of these, about 600 feet above the base, passes from near the Dolgelli road several miles to the northward. It is from 100 to 200 feet thick.* Further south, it doubles that amount. Northward, it thins entirely away before reaching 'R-allt-llwyd. Another well-marked but short band separates the Y-Dduallt felstone from the ashes. Others are of frequent occurrence, so small, however, and inconstant, and so apt to pass in all directions, gradually or suddenly, into pure ashes by the admixture of what was once volcanic dust and loose crystals of felspar, that, on the one-inch map they are inseparable from the more purely volcanic matter. These lenticular interstratifications represent on a larger scale, what takes place on a small one, in the case of flaky lines and other thin and short interlaminations of slaty matter among the ashes, and afford ample cause of perplexity to him who attempts to map out every alteration of the strata with minute accuracy. Sandy felspathic strata are also not unfrequent among the ashes, and, indeed, some of the beds for a space better deserve the name of sandstones than of volcanic ashes.

Intruded greenstones occur in the ashes. One, a quartz amygdaloid,† runs nearly in the line of strike; and the greater part of Craig-y-Benglog is also formed of greenstone intruded more irregularly and on a larger scale. This rock is green and also amygdaloidal, the vesicles being mostly filled with quartz, which is generally covered with a thin coating of very dark chlorite. It belongs to the same class as the vesicular greenstone that forms the summit of Cader Idris and part of the western side of Geu-graig.‡

Around this neighbourhood the felspar porphyry, as on Aran Mowddwy, is about 1,200 feet, and the lower ashes 1,300 feet in thickness; a great diminution for the latter when compared with the thickest parts of the same mass on the Arans, and about equal to their development on Moel-ddu at the north end of the Aran range.§

Further south, the rocks of Moel-Offrwm and Llanfachreth seem to be an outlying portion of the lower ashy series let in between four faults. It is, however, a very complicated bit of ground. The whole of the hill seems to be more or less interpenetrated by injections of greenstone, and while some of the strata seem to be ordinary rocky felspathic ashes, much of the material suggests the idea that it consists of ashy beds that have subsequently been altered and *baked* by heat probably connected with the associated greenstones. East and south-east of Llanfachreth the rocks consist of thick bedded undulating strata, often so sandy that they rather deserve the name of felspathic sandstones than of volcanic ashes. Some of them pass into pure sandy grits. On the low ground north of Moel-Offrwm there occurs a finely stratified slaty rock of an apple-green colour. The west flank of the hill consists of grits, a little slate, and felspathic ashes, the last predominating. A patch of altered slate occupies its summit, and the strata, as a whole, undulate easterly at low angles. In the Deer Park it is sometimes difficult to separate the greenstones from the ashes, for they are both of the same dark green colour, and the lines of stratification are sometimes so faint that it requires careful observation to detect

* Where crossed by the 6-inch sections (Sheets 29 and 37).
† Crossed by the section (Sheets 29 and 37).
‡ Map Sheet 59, Pl. 28, No. 1, and diagram fig. 6.
§ Fig. 8, and 6-inch sections, Sheet 37, lines 3 and 4.

them. The scattered crystals of felspar seem, however, to be mechanically mixed with, rather than crystallized in the matrix. Altogether these green ashes convey the impression that they may have been formed of volcanic dust, of similar composition with the substance that constitutes the greater part of the neighbouring mountain mass of Rhobell-fawr.

Beyond Y-Dduallt the ashes and overlying porphyry strike north to Moel-llyfn-nant, on which they curve round to the east and south in a small synclinal basin as shown in Fig. 16, p. 67, afterwards to be described.

Between the ashy beds and the rocks of Rhobell-fawr and from thence to Moel-llyfn-nant, there are slaty strata of various kinds. North of Y-Dduallt the Arenig slates and grit dip beneath the felspathic ashes and lavas, and in the slate it is stated that a *Trinucleus* was found. Tremadoc slate is also known, by the river north of Moel-gron, and the black streaked slate of the upper Lingula flags dips under the igneous mass of Rhobell-fawr all along its eastern boundary, in places containing *Lingulela Davisii*, and at Craig-bach, *L. Davisii*, *Olenus alatus*, and parts of *Conocoryphe*.

Near Blaen-lliw Arenig fossils were found by Professor Sedgwick and Mr Salter in 1843, 2 miles south-west of Arenig.

Both ashes and shales, south-west of the sixth milestone on the Dolgelli and Bala road, are interrupted by the Dolgelli and Bala fault, and by a branch dislocation which passes north-west by Ystum-gwadnedd, bringing the ashes near Llanfachreth into juxtaposition with the greenstone by a downthrow of about 1,000 feet. Following this dislocation the shale beneath the ashes is again let in at Cors-y-garnedd, between the greenstone on which it rests and the fault, and from this point to the river Wnion near Dolgelli, the ashes are brought against the greenstone, except at one small spot in the grounds of Nannau, by a north and south fault that passes through Llanfachreth.

As the greenstones of Merionethshire are not truly interbedded but intrusive, it is not easy absolutely to demonstrate these dislocations, nevertheless when we consider the winding contour of the rocks elsewhere, the directness of the supposed faults which often run in straight lines, and the fact that at the south-east side of Rhobell-fawr the black Lingula slates are cut sharply off by one of them, there remains but little doubt of their actual existence. The largest fault strikes from the river Wnion northwards through Llanfachreth to Aber-geirw-mawr on the river Mawddach near Craig-y-Dinas. It is a downthrow on the east, and the western boundary of the Rhobell-fawr greenstone runs unusually straight, in a manner that clearly indicates a prolongation of the line of dislocation near Pen-y-bryn, fig. 15.

Rhobell-fawr.—The immense igneous mass of Rhobell-fawr seems, in part at least, to lie irregularly on the broken edges of the Lingula flags in the manner shown in the following diagram, fig. 15.*

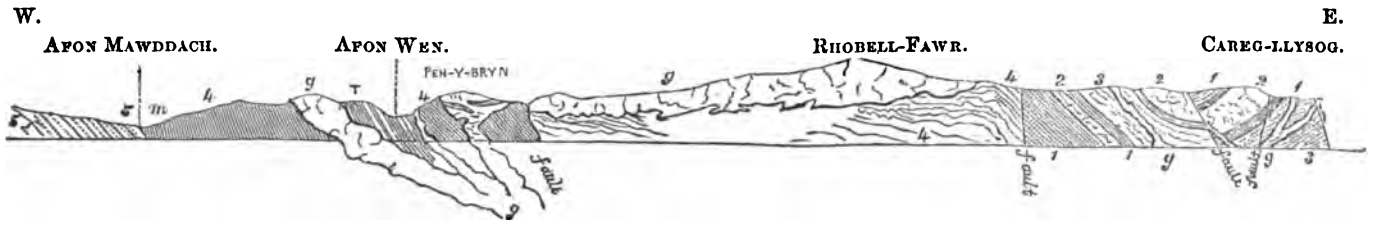
Rhobell-fawr occupies a broad tract of country, stretching from the banks of the higher part of the Mawddach, opposite Craig-y-Dinas, to Cae'rhedydd, 1½ miles south-east of Llanfachreth; from thence, at Ystum-gwadnedd, bending round northward by Moel-Cors-y-garnedd to Moel-gron and Rhobell-y-big. Near Llan-fachreth the boundary, which is a fault with a downthrow on the east, passes nearly directly north to the neighbourhood of Cyplau, and from thence, with a curving outline, strikes eastward towards Moel-gron, along the slopes on the south bank of the Mawddach. South of this, its eastern boundary trends with a very irregular outline southward to Caer-hedydd, bounded by black slates of the upper Lingula flags which dip west underneath the igneous mass.

Its greatest length from north to south is over 4 miles, and its greatest width from east to west about 2 miles. Outliers of the

* *See also* the sheet of 6-inch horizontal sections, No. 37, line 3.

Fig. 15.—Section from the River Mawddach, near Dol-Melynllyn, across Rhobell-fawr to Careg-llysog.

Scale 1 inch to a mile.



No. 1 represents the Arenig beds in the faulted synclinal axis already described at pages 50 and 51; No. 2 the felspar porphyry; No. 3 the lower felspathic and calcareous ashes and conglomerates; No. 4, east of Rhobell-fawr, the upper black Lingula flags of Merionethshire, which partly dip towards and under the igneous mass, and which are overlaid by Tremadoc slates further north; and 4 under and west of Rhobell-fawr Lingula flags lower in the series, including the talcose, pyritous, and cupriferous schist marked T; No. 5 represents the Cambrian grits at Pont-ar-Gamlan, dipping under the Menevian beds *m*, and Lingula flags, 4, at an angle of 50°. The igneous rocks *g* are drawn so as to show a kind of underground connexion that probably exists between the various masses exposed at the surface; and the rocks of Rhobell-fawr consist of masses of volcanic ashes and lava, the relics of a centre of eruption; now, at its edges, lying partly on the surface of the broken and crumpled black Lingula slates.

The Lingula flags of this neighbourhood, near Tyddyn Gwladys, Moel-Hafod-Owen, and north by Craig-y-Dinas, were, in 1865, carefully searched for fossils by Mr. Ezekiel Williamson. The result has been the discovery of a great number of forms lying in well-marked zones. In a band of Menevian slate not far above the Cambrian grit the following fossils were found:—*Obolella*, *Obolus*, a small *Lingulella*, and *Theca corrugata;* of trilobites, *Agnostus princeps*, *Microdiscus punctatus*, and *Anopolenus Henrici*. In a higher bed, on the bank of the Mawddach, *Paradoxides Davidis* occurs in great numbers. Higher still, on the western flank of Moel-Hafod-Owen, in Lingula flags, *Olenus Cataractes*, *O. micrurus*, and *Agnostus*. In higher beds, on the same hill, a new fucus *Buthotrephis Cambrensis*, with *Lingulella Davisii*, *Conocoryphe*, and *Olenus*. In the upper part of the Lingula flags, towards Craig-y-Dinas, there were found *Orthis*, *Palæarca*, *Lingulella*, *Agnostus princeps*, and *Olenus;* and near the top, *Lingulella*, *Agnostus princeps*, *Dikelocephalus? Olenus scarabæoides*, *O. pecten*, *O. bisulcatus*, and *O. humulis*. The whole resembles the rocks of St. David's described by Mr. Salter and Mr. Hicks, and above these Mr. Plant considers that he has found Tremadoc slates.

same rock form the summits of Moel-gron and Craig-y-Dinas, so that before denudation it originally spread much further.

The surface of this mountain mass is barren and broken, and for long its vast succession of tumbled mounds has conveyed to me the impression of successive ejections of volcanic matter from some concealed vent which piled themselves on each other. On its western boundary south of Pen-y-bryn and from thence to Dolgelli, a mass of greenstone branches in many irregular forkings due perhaps partly to contortion of the strata, but more often (for instance, at Llyn Cynwch, and between Llanfachreth and Pen-y-bryn) as the result of the injection of veins of greenstone, more or less, in the lines of bedding, before these contortions took place. Whether or not these rocks have any direct connexion with the mass of Rhobell-fawr is problematical. Intricate interlacings of slate also occur scattered over Rhobell-fawr, generally so small, that it is impossible to map them, but one marked example occurs on the summit, where the slates are so altered and mixed with small injected veins of greenstone, that it is almost impossible to separate them in mapping. Intense alteration of the shale or slate is, however, exceptional. On the east and north-east they are black and carbonaceous, and therefore, perhaps because of their bad conducting quality, they are but little altered even close to the greenstone under which they there dip.

Along its western boundary the slates are generally of a lighter and sometimes of a more rusty hue, like ordinary banded Lingula flags. They contain many gritty beds, and on Moel-Hafod-Owen, where *Lingulellæ* are abundant, the strata are very much disturbed and altered, small bosses of greenstone being protruded here and there, which it is presumed are possibly connected underground with the melted matter, the ejection of which helped to form what is now Rhobell-fawr, and with the three detached patches that lie between Moel-Cynwch and the south-western slope of Moel-Hafod-Owen.* From the more felspathic greenstone of Hafod-y-fedw on the opposite bank of the Mawddach, a little more than a mile north of Llanelltyd, veins have been injected into the slate, which is hardened at the junction.† These are distinctly intrusive, for not only do they alter the rocks, but the most northerly patch branches straight across the strike of the slate, forking out in various directions on the hills between the rivers Mawddach and Eden. Two branches of this injected mass are shown in the large horizontal section, sheet 29, line 2, immediately west of the Mawddach, and in the drawing it is unconnected with any greenstone intruding from below, its junction with the main body of the rock taking place about a quarter of a mile further south.

If we take a general view of the strata that surround the mass of Rhobell-fawr the following is the result. On the south, beds of felspathic ashes are thrown against it by two faults,

* Moel Cynwch lies 2 miles north of Dolgelli, Moel-Hafod-Owen 2 miles W.S.W. of the summit of Rhobell-fawr.

† *See* section, Sheet 37, lines 2 and 3.

one of which is a downthrow on the south-east and the other on the south-west. In like manner on its western boundary, in connexion with a north and south fault it abuts on lower Lingula flags, which in ascending series also form its northern boundary, while on the east to the west of a north and south fault which has a downthrow on the east, the black slates of the upper Lingula flags dip towards and apparently under the igneous masses.

The precise origin of the mass of Rhobell-fawr is difficult to explain with precision. Ascending from the east near Moelcors-y-garnedd we first find greenstone well crystallized with a fair development of uralite,* on the west of which lies a short band of altered slate about three quarters of a mile in length. Between this and the summit of the mountain the rocks consist of great rubbly brecciated-looking masses, containing angular and sub-angular stones, some of which are vesicular and contain crystals of felspar which also occur in the matrix that encloses the stones. This base is often blue and felspathic-looking, and sometimes encloses numerous elongated rectangular crystals of what was once augite, but is now hornblende from an eighth of an inch to an inch in length. Occasionally, for a yard or two, there seems to be irregular lines of bedding in the masses of bare rock, which everywhere in confused solid mounds forms the surface of the broad spreading hill, but such traces speedily die out, and show no clear regularity of strike. Here and there short inconstant streaks of highly altered slate lie in among the igneous matter. On looking back towards the summit on the rough slopes that form the west side of the hill, an uncertain terrace-like aspect is vaguely distinguishable, but this may be deceptive.

Taken as a whole, the great mass of Rhobell-fawr is larger and more central than any of the eruptive bosses of more purely felspathic material that lie within this volcanic area, as for example that of Y-foel-ddu west of the peak of Aran Mowddwy, and it may be asked whether or not it may have been a centre of eruption. It is certainly the case that the greenstones that help to make the mass of the mountain, and some others, such as that of Hafod-y-fedw near Tyn-y-groes, contain more felspar than hornblende, though this is by no means the most prevalent type. The great beds of felspathic perphyry, once lava flows, never contain much hornblende, and only in exceptional cases does hornblende occur in sufficient quantity to entitle them for a little space to be doubtfully classed with dioritic rocks. As the felspathic ashes of the country in general have been simply formed of felspathic lava, ground up *in* and *blown* from the craters of volcanoes, they generally present an aspect in material and colour, resembling the undoubted lava beds, while, however, it must be allowed, that the ashes of Moel-Offrwm† often resemble in colour the more massive rocks of Rhobell-fawr.

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* A pseudomorph of hornblende after augite.
† About a mile S.S.W. of Llanfachreth.

Having always had a doubt about the correctness of the explanation of the precise geological structure of Rhobell-fawr given in the previous edition of this work, I requested Mr. J. C. Ward, while tracing the Arenig grit to turn aside and examine the mountain, and afterwards in 1875, accompanied by Messrs. Homfray, Etheridge, Ward, and Hebert, I spent great part of a day on the hill in reviewing my old impressions.

It had previously occurred to Mr. Ward that probably all the phenomena might be explained on the supposition that this area was a centre of eruption, and that the present confused mingling of volcanic breccias, greenstones, and lines of altered slates, may have been brought about by the subsidence of volcanic materials, consisting chiefly of ashes and lavas, into and round the area of a large central crater after its volcanic energy declined. Assuming this to have been the case, we may suppose the crater to have been a marine one, on a greater scale than that of Graham Island in the Mediterranean (now destroyed), and that the patches of mud (now altered slate), were deposited on its sides during the long continued accummulation of various kinds of material successively ejected from the crater.

Mr. Ward's written account of the mountain is as follows :—

"The rocks of Rhobell-fawr, with the exception of a few small patches of undoubted greenstone, seem to be mainly of volcanic origin. The greatest thickness of beds exposed in a clearly continuous section, from the base on the south side to the summit, consists of alternations of coarse ash, breccia, and slaggy or scoriaceous breccia, with which are mingled in many parts numerous crystals of hornblende, some of them attaining a very large size. A little to the south-west of the summit there is a line of probable faulting, on the north-east side of which some well-bedded ash and ashy-slate beds come on, forming the summit of the mountain. A little below the summit an oblong angular block of grit (probably Arenig grit) was found, about 15 inches long, but no traces of the grit bed were met with. On Rhobell-y-big a splendid development of breccia occurs, though even here, in the most decidedly fragmentary portions, hornblende crystals or fragments of such occur. The outlying rocks forming Craig-y-Dinas and Moel-gron are much more trap-like, that of the latter being quite free from any fragmentary structure, and consisting of a compact bluish base with disseminated crystals of hornblende (or perhaps some augite). The original connexion of these masses with the main mass is, however, quite clear.

In some parts of the large area of Rhobell, it would seem as if the originally fragmentary rock had undergone a large amount of alteration, but in every part the apparently ashy structure is clearly seen here and there, while occasionally the rock exhibits imperfect cleavage, and is certainly very different from most of the crystalline greenstones of the country. This Rhobell-fawr mass differs from the other ashy strata of the district in the following points :— 1. Bedding is scarce ; 2. The fragments are often very large and apparently never rounded ; 3. Crystals of hornblende, or fragments

of such, are commonly mingled with the fragmentary material. On the whole, the evidence rather suggests that the rocks in question represent a centre of volcanic eruption breaking out after the close of the Tremadoc slate period, the material erupted being of a slightly different nature to that now forming the widely-spread felstone and ash beds of Arenig and Llandeilo age. It is easy to understand how the actual focus of eruption might become hidden under ashy accumulations, and the relations which may have existed between various volcanic masses are rendered difficult of interpretation on account of the subsequent folding of the strata. It is worth noticing that, geographically, this large and irregular accumulation of volcanic material stands in a very central position with regard to the great Arenig series of lavas and ashes, which die away to the north-west near Tremadoc, and to the south-west near Towyn."

There are certain stratigraphical difficulties connected with this explanation which will be best understood after I have described the structure of the Arenigs and Moel-Llyfnant, when I will return to the subject.

CHAPTER VIII.

Talcose Rocks, and other Copper and Gold-bearing Beds of the Mawddach Afon-yr-Allt, &c.

In 1852 I gave an account of part of the geology of the gold-bearing district of Merionethshire, in a paper communicated to the Geological Society, portions of which I here extract with additions and some minor alterations.

On the north and west of the lower part of the river Mawddach lie the Cambrian rocks, the Menevian beds, and the Lingula flags. A well-marked portion of the Lingula beds, composed of rusty ferruginous slate, occupies part of the cliff of Moel-Cynwch that overlooks Dol-fawr.

Both Cambrian and Silurian rocks have been penetrated by numerous greenstone dykes. Many of these are of a light grey colour, highly calcareous, and effervesce on the application of an acid. One is magnetic. Among the Cambrian rocks they run in all directions, sometimes with, but more generally across the strike. In the Lingula flags they often run more or less parallel to the lines of bedding. Some of them fill cracks and pass into lines of lodes. A case of this kind occurs on the north and west of Tyn-y-groes. A strong lode, bearing quartz and lead-ore, commences between Dol-y-melynen and the fifth milestone on the Dolgelli and Trawsfynnydd road. For about three-quarters of a mile it divides the Cambrian and Silurian rocks. Passing into the former at Cefn-coch, the fracture as it crosses Craig-y-Cae and Y-garn becomes filled with greenstone. Several other metalliferous lodes occur in this neighbourhood, and in general

they all traverse the Lingula flags or their associated igneous rocks. There are four quartz-lodes bearing a little copper in a mass of trap that lies west of the road between the third milestone and Tyn-y-groes. Three near Tan-'rallt once known as the Tarian lodes run north and south, and the other at Cae-mawr strikes east and west. All of these, many years ago, were worked for copper without much success. On the opposite side of the Mawddach at Glasdir-isaf there is a copper mine which has been opened since the geological map was made. It was tolerably successful and is still worked a little. A little gold is found with the copper in this lode. There are also two quartz-lodes bearing lead-ore a little north-east of Moel Ispri, and at least seven similar lodes yielding copper ore on the hills immediately north-west of the Barmouth road, between Llanelltyd and the fourth milestone from Barmouth.

In the country, not far south of that in which the Dol-y-frwynog mine lies, an igneous mass breaks through a low part of the Lingula beds, and occupies the heights on which stand the houses of Tan-'rallt and Hafod-y-fedw. Three of the lodes already noticed as yielding copper ore lie on its eastern slopes; and I was informed by Mr. Byers, that a little gold was detected in one of them, in 1836, by Mr. O'Neil.

For four or five miles north of this area several other lodes occur in the Lingula flags and their associated traps, on the banks of the Mawddach and of Afon-yr-Allt. The general geological relations of the rocks of this country between Rhobell-fawr and the Cambrian rocks will be understood by referring to the section Fig. 15 p. 55.

East of the greenstone marked *g* are a set of rocks which possess a very peculiar lithological character, and which occur very sparingly elsewhere, either among the Lingula flags or in any other area in Wales. It is in this "country" that some of the gold-bearing lodes occur and were worked. The rock begins at the south-west angle of Moel-Hafod-Owen above Buarth. The east and west fault that bounds the greenstone limits it on the north, and a north and south fault about a quarter of a mile east of the igneous mass, bounds it on the east as far as where the brooks join nearly opposite Dolau. From thence Afon-yr-Allt forms its boundary for nearly a mile and a half south. The boundary line then crosses the stream, and by Ffridd-goch passes through the wood and along the west side of Cefn-mawr where it ends against the igneous mass of Moel-Cynwch.

The rock that forms this tract is one of those problematical masses to which it is difficult to give a definite name. In places it is so hard and massive, that a hand-specimen can scarcely be distinguished from some of the felspathic igneous rocks of Merionethshire. Even then, however, it is more or less flaky, and constantly passes into a talcose rock, which in places on the surface of the ground and in lodes, decomposes into a kind of talcose unctuous clay. In many places it graduates in the line of strike into the ordinary slaty rocks of the Lingula flags, which then

become interstratified with it. Going southward, it becomes more and more slaty and sandy, and finally passes by degrees into the ordinary Lingula flags of the district.

Several lodes occur in this country in the neighbourhood of Dol-y-frwynog and Cwm Eisen. The gold in Cwm Eisen was discovered in 1843 by Mr. Arthur Dean, who, in a paper published in the Reports of the British Association for 1844, stated "that a complete system of auriferous veins exists throughout the "whole of the Snowdonian or Lower Silurian formations of "North Wales." This bold statement, it is needless to add, has never been confirmed, though gold has been found in the lodes of Dol-y-frwynog, Clogau, Vigra, and elsewhere, where mines have been opened and closed several times, and from this circumstance it would appear that they have not in general yielded a steady profit. The gold at Cwm Eisen was found in a branching lode containing lead-ore. Its principal branch runs north-easterly, and is mostly composed of exceedingly hard quartz, which crosses the river about half a mile above Rhaiadr Mawddach.

Of this mine Mr. Warington Smyth remarked in 1862:—"In "1846 I had the opportunity of examining some of the more "notable lodes near Dolgelly, in the district which had most "attracted attention. The Cwm Eisen mine, originally opened to "work some lead veins, had just been sold as a 'gold mine' for "14,000*l.*, neither buyer nor seller having made the slightest "approximation to an estimate of the length, breadth, or depth "of the auriferous ground, or of its fair average yield The "assays and experiments made by Mr. Clement, who was called "in to act as metallurgist, showed that the specimens contained "a proportion of gold which would be considered highly profitable in the old gold mining districts of Salzburg, of Hungary, "and of America. Great expense was incurred by Mr. Bruin, "the new owner, not in working the ground, or in erecting apparatus under the advice of men who were practised in gold "mining, but in following out the contrivances of ingenious "schemers; and the result was a very early suspension of all "operations."*

On the north-west side of the Mawddach, a little north of where it joins the river Gain, three parallel quartz veins were discovered. They run east and west or nearly so, and are crossed at right angles by several others. The veins, which are small, lie near Gwyn-fynydd, below Moel-gwyn-Cynydd. They were worked for lead and gold, and I was informed by Mr. Smyth that in 16 places specks of gold had been observed in them. The Tyddyn-gwladys lode close to Rhaider Mawddach was worked for silver lead without much success. The lode of Cwm-eisen-isaf was opened for lead. It is now stopped. Cwm-eisen-uchaf lode was first worked for lead, and later for gold, "and not much of it."

It is also said that gold has been detected in other places in the neighbourhood, at Craig-y-Penmaen, and in an east and west

* The Mining and Smelting Magazine, vol. i., No. 6, June 1862.

lode at the south end of the igneous mass of Craig-y-Das-eithin near Gelli-gain, about three miles S.S.E. of Traws-fynydd. I am, however, unable to say if the authorities from whom I obtained this information are to be depended on.

Further south, on the hills above the estuary of the Mawddach, mining speculation has been occasionally rife for many years, chiefly in lodes that lie in the Menevian and Lingula beds, south of the confluence of the torrents that rise in the Cambrian grits of Llawllech, and run southerly down the valleys of Hirgwm and Cwm-Llechau. Originally the lodes of Vigra and Clogau, the property of the Crown, were worked at intervals for about 80 years for copper, with little or no profitable result, but about 1854, the discovery of gold in the rejected rubbish of the old workings at Clogau, and also in the abandoned lode, raised a kind of gold furor in North Wales, which some persons remember to their loss. The gold had been previously known to the miners as "funny metal," and was considered to be worthless. After 1859 the gold-bearing vein, named "St. David's lode" which intersects the rocks about a quarter of a mile further north than the old Clogau lode was for a time worked to great advantage. "The vein itself," says Mr. Smyth, "where well developed, is from 2½ to 9 "feet in width," and "is composed of quartz and calcareous spar, "the latter sometimes forming a body several feet in width; and "when the calcite puts on the appearance of a finely granular "and friable marble, it frequently contains gold; when, on the "contrary it is large and coarsely foliated, it appears to be "entirely wanting in the precious metal." I have been told that in one year 21,000*l.* worth of gold was extracted from the Clogau and St. David's lodes, and it is reported that from the first opening of the mines from 100,000*l.* to 150,000*l.* of gold have been taken from the Clogau and St. David's mines. In 1873 the Clogau mine was re-opened, and till the end of 1879 it always paid its cost, and occasionally much more. In the present year the same lode on a lower level is being driven into in the hope and expectation of a successful result.

About two miles east of Clogau, on the hills above Llanelltyd, are the lodes of Caer-beudy, one of which was worked for copper and the other for lead, but with what success I do not know. In the same neighbourhood in Cwm-gwynyn I was informed that at one time a group of lodes were worked for lead and zinc with little or no success.

Next in date after the discovery of the St. David's gold lode comes that of Cefn-coch, which hill lies about two miles north of Llanelltyd. On the whole it was not a success, but about 15 years ago, as I was informed by Mr. Morgan of the Clogau mine, "a good many pounds weight of gold were got from pockets." It did not, however, pay on the whole. Before it was worked for gold the lode had been worked for lead.

It was also currently reported that gold was found in a lode in the Cambrian rocks a little further north, and at Cae-gwernog, Perth-lwyd, the Prince of Wales mine at Gallt-yr-hafod, West

Vigra, &c. in that neighbourhood, and it was said that gold was got from a lode to the extent of two or three ounces per week, about three miles west of the south-west end of Bala Lake in a faulted area close to the felspathic porphyry near Castell-carn-dochan. Of all these last, I know nothing personally, and when, 20 years ago, rumours were rife and mushroom companies springing up in all directions, I did not always give implicit belief to all that was said about gold.

Other lodes intersect the country, both proved and unproved. North-west lodes lie a little west of Moel-Hafod-Owen, two of which (one of them argentiferous) cross the river about half a mile below the waterfall. Other copper-bearing lodes intersect the valley between Moel-Hafod-Owen and the hills on the south above Dol-y-frwynog.

About a mile west of Llanfachreth is the Glasdir-isaf copper lode. It is still worked a little with moderate success. A little gold occurs with the copper.

On the west side of Afon-yr-allt, a small tributary of the Mawdach, a little to the west of the great igneous mass of Rhobell-fawr, there are two lodes with a N.N.W. and S.S.E. strike. They lie close to the spot known as Murddyn-coch-yr-aur, about half a mile south of the lodes of Dol-y-ffrwynog, and are known as the lodes of Cae-nant-hull. They are said to have been worked by the Romans, and are now considered to be of no importance.

In 1853 the most promising gold-bearing lode in the country was considered to be that at Dol-y-frwynog. It runs W.N.W. and E.S.E., in the low ground south of Moel-Hafod-Owen, and is principally composed of white saccharoid quartz, irregularly traversed by numerous small loose joints. Chlorite, decomposing talcose matter, and pink carbonate of lime are intermingled with it. In parts the quartz assumes a semi-granulated aspect, profusely intermingled with soft, unctuous, decomposing talc. It is often largely charged with iron-pyrites. As a rule the lode is easily shivered into fragments. It was first opened in search of copper; and a shaft was sunk to a depth of about twenty fathoms. During the process it proved to contain more attractive metal. On examining a heap of quartz which lay at the mouth of the shaft, I readily saw, with the naked eye, gold in small flakes and grains, irregularly disseminated through the quartz. In a more select heap of quartz, on all the pieces it was distinctly visible to the unassisted eye; and one mass in particular, heavier than a strong man could lift, was literally spangled all across its surfaces with glittering gold. Gold was also detected by Mr. Byers in the matrix of the old copper-bearing lodes of Cae-nant-hull,* and in the west Dol-y-frwynog lode close to the spot marked Turf Copper Mine on the map. All of these occur in the same talcose rock. A portion of this rock, however,

* This name is not on the map.

taken from the wall of the Dol-y-frwynog lode, was analysed in Dr. Percy's laboratory by Mr. Richard Smith. It yielded no gold.

On the banks of Allt-y-wenallt about a mile above the bridge, Mr. Byers stated to me, that there "are some ruins of buildings, "and below them, close to the river, the remains of charcoal "ashes and bits of bones mostly covered with herbage, This "place has a very singular and significant name, which it has main-"tained from time immemorial, expressive of gold having been "melted or worked there. This name 'Murddyn coch 'r aur' sig-"nifies 'the ruins of red gold.' The tradition is that the Romans "formerly worked gold there. It may be well to observe to those "unacquainted with Welsh names, that no ancient place has a "name but what is generally characteristic of its locality, or of "some event that has taken place on or near the spot." The old Roman road, called Sarn Helen, runs northerly very near this spot.

I may also state, on the authority of the late Mr. Byers, 1853, that in several spots in this neighbourhood where quartz lodes occur, associated with ores of copper, blende, lead, and talc, there gold has been found, instances of which he cited as occurring at Tyn-y-Llwyn, near Moel Ispri, and other places, principally in the Lingula flags between Tyn-y-groes and the Mawddach, towards Barmouth, all of which I have already noticed. Mr. Byers also stated that gold has been detected north of Cwm Eisen; as for instance, at Penmaen, and at Gelli-gaen, about three miles S.S.E. of Trawsfynydd; also in the old Newborough mine, in an east and west lode immediately north-east of the Manods, and also on the south side of Moelwyn in blende and gossan. I give but little credit to these old reports, and can answer for few of these localities personally. The whole of these places lie either in the Lingula-flags, or in the strata immediately adjoining.

If in some of the lodes of the country gold be found, then we might expect that it would be detected in the detritus that lies in the neighbouring valleys. Gold, in appreciable quantity, was, it is said, found by washing in the bed of the Mawddach, in the summer of 1852, by the Honourable Frederick Walpole and Sir Augustus Webster (then Mr. Webster). Mr. Byers and myself, at a later date, spent a whole day with the same object and found none. Should the attempt ever be repeated, it would be well to cut through the alluvial and other superficial deposits of the Mawddach and Allt-y-wenallt down to the solid rock, in the hope that such a heavy substance as gold might be somewhat concentrated at the bottom. I doubt, however, if even this would be a hopeful project, for in a country the valleys of which have all been thoroughly scoured out by glaciers, which are no respecters of relative weights of materials, gold and stones would all alike be passed onward and out to sea, and who can say, that since the close of the glacial epoch enough of time has elapsed, by the natural waste of the hill-sides and lodes, for later accumulations

of gold to have taken place in the alluvia in any merchantable quantity.

It was in this country, more than half a mile west of Dol-y-frwynog, that the once famous Turf Copper Mine was situated in the heart of the talcose schist, which almost everywhere contains much iron-pyrites in small crystals, scattered through the rock, together with specks of yellow sulphide of copper. Very small veins of this ore also intersect the mass. A peat bog occupied the greater part of the bottom of the valley. The turf was pared off the surface and burned in kilns, and being partly saturated with some compound of copper a large residue of valuable copper was left in the ashes. Many thousand pounds worth were thus extracted. The neighbouring hills were afterwards burrowed in all directions in search of the great lode, or bunch, from whence the copper was supposed by sanguine adventurers to have been carried in solution to the peat. It was never found and probably does not exist; the water that percolated through the rocks, and rose in springs, having more probably carried the copper, in the form of a sulphate, from those minute quantities of the sulphide that are more or less diffused through the mass of the hill that overlooks the Turf Copper Mine, in the peat-moss of which the copper was diffusedly deposited.

Far west of the lodes that have been mentioned in this chapter there are several so-called Manganese lodes in the Cambrian rocks. One of these on the hills about a mile from Barmouth strikes straight north for a length of about two miles. Another about three miles further north runs northerly near two well-known Cromlechs, and a third in the same neighbourhood runs north and south along the steep west side of Y-Foel-wen. In miners' phrase I have called them lodes, but when many years ago I visited them, they seemed to me to be merely certain parts of softer strata impregnated with oxide of manganese in the line of strike, that is to say, at right angles to the dip of the Cambrian beds, as shown by the arrows on the maps. (Sheets 59 N.E. and 75 N.E.)

CHAPTER IX.

The Arenigs, Llyn Conwy, and the Rocks in their Vicinity.—Fossils.

General Description.—The rocks of the Arenig mountains, and the district of Migneint and Llyn Conwy, lie on the same stratigraphical horizon with those of the Arans, and exhibit the same class of phenomena, for the component parts are repetitions by the Bala fault of the same masses, some of them developed on a greater and others on a smaller scale. The felstone porphyry, west of Bala Lake, over which flows the river Lliw,* has already been partly described,† and in doing so I have mentioned the ashes that *overlie* it, and *underlie* the black slates of the Arenig beds. Ashes in the same general position are, indeed, also found overlying the great masses of porphyry that form the crests of the Arans and Cader Idris. But where the igneous series is repeated by the great Bala fault, these *upper* ashes thin away west of the Bala road, about 3 miles south-west of Llanuwchllyn. Gradually becoming more developed as they pass north towards Arenig, they attain eventually a thickness of about 700 feet, and dipping east, form the entire eastern flank and summit of the mountain (Fig. 16).‡ The *lower* ashes that rise from underneath the felstones of the western range§ strike by 'R-Allt-llwyd northwards to Moel-llyfn-nant, and while the ashes above the felstone by degrees thicken, the lower series gradually decline in their northward passage and beyond Moel-llyf-nant they cannot be precisely identified. The felspathic trap, however, still continues; for the same rock that forms the summit of Moel-llyfn-nant crops out half-way up the western flank of Arenig (Fig. 16), directly overlying the Arenig slate.

North of Arenig-fawr (maps 74 N.W. and 75 N.E.) the *upper* ashes cover a broad area, spreading eastward to Craig-ddu in the great anticlinal curve of the strata north of Bala, and thence strike west and north by Llyn Conwy to the river Machno. Through all this area, excepting on faulted ground, the ashes are directly overlaid by dark blue and black shales and slates, and underlaid, as the fossils of Tai-hirion testify, by the lowest Arenig beds.

Beyond this point for several miles, lower ashes only appear beneath the porphyry in a few streaks near Cerig-y-Bala and Tai-hirion in the district of Migneint.‖ The following diagram, Fig. 16, will explain some of these particulars:—

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* Misspelt Llin in Map 74 S.W.

† Pages 50 and 51.

‡ Six-inch section, Sheet, No. 39, line 1.

§ Between Y-dduallt and Moel-llyfn-nant.

‖ Cerig-y-Bala is about 6 miles east of Ffestiniog, and Tai-hirion about 1 mile S.W. of Arenig-bach.

Fig. 16.

SECTION ACROSS MOEL-LLYFN-NANT AND ARENIG TOWARDS BALA.

No. 1 represents the black slaty shales of the Arenig beds, which further south occupy part of the low drift covered ground between Bala and Arenig. No. 2 shows the position of the upper ashes. A thin band of Arenig slate, No. 3, here separates it from the felstone, No. 4, which, at the base of Arenig, rests directly on the Lower Arenig beds, No. 6. An anticlinal curve in the hollow throws the same strata over to Moel-llyfn-nant, where the lower ashes, 5, come between the Arenig beds, 6, and the felspar porphyry No. 4, No. 7, is the grit at the base of the Arenig beds, and, 8, Tremadoc slates. *f*, faults. *g*, represents injected greenstones, also irregularly repeated in the anticlinal and synclinal curves.

Where the foregoing section crosses the country, the porphyry is only about 300 feet thick, but on the north side of Arenig, on the crags of Maen-grygog and Daear-fawr, and on the opposite bank of the river between Y-foel and Bryn-maen-llifo,* it greatly increases in bulk. It consists of dark grey porphyry, with small distinct crystals of yellow felspar in a felspathic base, but further north it gradually becomes less porphyritic. In some places it is columnar, and in others largely jointed. It disappears close by Llyn Serw, between Arenig-bach and Ffestiniog.

The greater part of Arenig and about 15 square miles on the north (including Mynydd Nodol, Arenig-bach, Craig-ddu, and Lechwedd-llyfn) consists of wide spreading undulations of the upper felspathic ashes, overlaid by dark blue and black Arenig slaty shale. The large maps and sections† show, that part of the volcanic area owing to undulations of the strata, is widely covered by about 800 feet of ashes. Fig. 16 partly explains this area. Here and there it is faulted. One of these faults, about half a mile east of Llyn Arenig, strikes northerly, and throws in the Upper Arenig beds on the west.‡ It is met by an east and west fault on Cefn-llwyn-y-bugail, which throws the same strata against the trap on the south. Several other faults on the north-east affect the strata on a broken synclinal line between Gylchedd and Moel Phillip. Others occur south of Garn throwing in the Arenig beds in a broken synclinal between hills of volcanic ash. At Waun-Carnedd-filiast the ashes form a sharp angle caused by the meeting of north and north-west faults that each affect the Arenig and Bala beds, one being a downthrow on the east, the other on the north-east.§ The shift of the beds in the largest of the two probably does not exceed 500 feet.‖

The ashes of Arenig are difficult to describe with precision. In some places (as, for instance, near the top) they are decomposed and shivery, and in others rough and almost scoriaceous looking. On the bare steeps that surround Llyn Arenig they are thick-bedded, and frequently porphyritic, but so massive, and they so much resemble some of the true felstone porphyries that the observer is apt to doubt of their truly stratified character, especially as it frequently happens that they are so much jointed that in places they look almost columnar. Still, when viewed in favouring lights on a large scale, the long lines of massive beds that streak the steep flanks of the hills generally become sufficiently apparent, and when traced along the strike to Mynydd Nodol and Arenig-bach all doubt ceases, for, by degrees becoming less jointed and massive, their true bedded structure comes out with perfect distinctness. Nevertheless it must be confessed that on Arenig, and for some distance further south, the subject is

* Under Arenig-bach.

† Maps 74 N.W. and S.W., and 6-inch sections, Sheets 29 and 31, and lines 1 and 5.

‡ Diagram, Fig. 16, and 6-inch section 39, line 1.

§ Gylchedd lies 2¾ miles S.S.E. and Waun-Carnedd-filiast 3 miles south-east of Yspytty Evan. Moel Phillip and Y-Garn about 4¼ miles north-west of Bala.

‖ Maps 74 N.W. and S.W., and Section, Sheet 31, line 5.

beset with difficulties which probably arise from the partial metamorphism by heat of parts of the ashy series of strata.

"In some places," says my colleague, Mr. Aveline,* "it is quite "impossible to draw any definite line between the porphyry and "ashes. They seem to pass imperceptibly into each other, and "the fact that some even of the massive felstones have a bedded "appearance makes the separation still more difficult. When "much decomposed there is no apparent difference between them. "When you go over the ground between Llyn Conwy and "Arenig-bach, and see these bedded rocks rolling and undulating "across the country, you cannot hesitate as to what they are; "and again, if you examine the massive rocks south of the "Arenigs, often undoubtedly columnar, you would at once decide "that they are good trap rocks. But if one person were to trace "the ashes from the north, and another the traps from the south, "each would carry his lines well into the territory of the other. "Possibly these difficulties may be accounted for as follows. In "the Arenig area the ashes and the trap were not formed as "distinct masses by different eruptions, but they may have "accumulated at the same time, the trap not extending much to "the north where the accumulation of ashes was greatest, and on "the south, where in a less degree the ashes also fell, they may "have got mixed with and been partly melted by the hot lava-flows, "and in other cases been hardened and altered, but not so com-"pletely as to have lost their bedded appearance. These remarks "only refer to the upper ashes, and in some respects do not apply "to the felspathic porphyry under Arenig, which appears some-"what different from the rocks further south, and I am not sure "that it is not partly intrusive." The probability of this is not diminished by the presence of certain small bosses of porphyry on the west in the district of Migneint, and near Llyn Treweryn.† These are probably intrusive, and may possibly represent some of the volcanic necks through which the lava rose towards the surface.

Throughout a large part of of this region the lines of stratification form a striking feature in the landscape, giving a distinct character to the hills of Mynyddd Nodol, the broken ridge by Afon-Hescyn, Llechwydd-llyfn, and Arenig-bach. On Arenig-bach itself they lie in long terrace-like lines on the western and northern crags, and from its summit an experienced eye can follow the flowing undulations of the strata on the flanks of the eastern hills. Some of the rocks are thick, massive, and porphyritic; others are thinly banded, and in places almost slaty-looking. Occasionally the beds weather slaggy and harsh, but even then retain their well-stratified character. Between Arenig-bach and the river Machno‡ the same porphyritic brecciated and bedded ashes occupy a large part of Migneint and the hills round Llyn

* MS.
† Llyn Treweryn lies 6 miles E.S.E. of Ffestiniog.
‡ Two miles south-west of Penmachno (Map 75 N.E.).

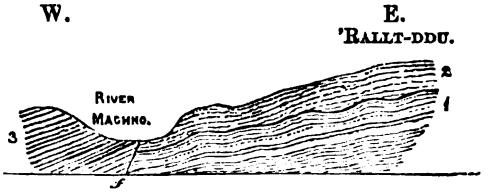
Conwy, and through all this district they are sparingly intermingled with short lenticular slaty bands.

The Tai-hirion fault, which is of considerable magnitude, passes southward across Migneint, throwing down Bala and Arenig beds on the west at Trinant against the ashy strata, while further south beyond Morch-awgrym the lower Arenig slates and grit, the Tremadoc slates, and upper Lingula slates abut on the volcanic ashes and porphyry in the line of fault which is a downthrow on the west.

The rocks between Arenig-bach and Afon-Conwy are obscured by peat-moss and drift, but enough here and there crop to the surface to render the boundary tolerably approximate. From Pont-ar-Gonwy to the Machno it is sufficiently distinct. On Bryn-rhuddod* the strata lie nearly flat, but in general the ashy beds undulate to the east on the summits of the hills. A good section is exposed on the north shore of Llyn Conwy. The strata dip easterly from 8° to 12°. Between Llyn Conwy and the Machno they undulate northward and eastward, and finally dip towards the Machno fault, coating the hill that slopes to the river, and crowning the cliffy bank that overhangs the high road between Hafod-yr-edwedd and Caregog, in the manner shown in the following diagram :—

Fig. 17.

SECTION FROM 'RALLT DDU, NORTH OF LLYN CONWY ACROSS THE RIVER MACHNO.



1. Arenig slates.
2. Felspathic and porphyritic ash.
3. Bala beds. *f* fault.

As a whole the ashes of Migneint and the country near Llyn Conwy dip eastward under the black slate of the Arenig beds at angles between 20° to 30°. These slates are the equivalents of those that directly rest on the igneous rocks of Arenig and Aran Mowddwy.

* One mile south of Llyn Conwy.

CHAPTER X.

RHOBELL-FAWR AND ITS RELATION TO THE LINGULA FLAGS, TREMADOC SLATES, AND ARENIG SERIES.

In previous descriptions the grit at the base of the Arenig beds, after being lost for a time on Cader Idris, has been traced northward along the western slope of the Arans as far as the great Bala fault about two miles south of Llanuwchllyn. The natural place to look for it in this region is in the strata a little way beneath the ashes that underlie the main mass of the interbedded felspathic porphyry (Fig. 3, Pl. 28). But between Rhobell-fawr and the long lines of felspathic ashes further east no trace of the grit is found till we reach the latitude of Y-Dduallt. From thence, broken by occasional faults, it has been traced by Mr. Ward and Mr. Hebert as far north as Tai-hirion, while beyond that to the west, I began this work by tracing the same grit from Tai-hirion to Criccieth. The line, therefore, from Llanegryn, 6 miles south of Barmouth to Criccieth is tolerably complete and has been traced for about 50 miles (with two short interruptions) running parallel to the great curved line of felspathic lavas and ashes that lie south east and north of the central boss of the Cambrian grits and slates of Barmouth and Harlech.

It having been shown that the felspathic ashes and porphyries always lie in the horizon of the Arenig beds above the grit which is generally present, it may be assumed as probable that the geological history of the igneous mass of Rhobell-fawr is in some way connected with the truly interbedded lavas and ashes of the Arenig series (Lower Llandeilo of Murchison).

It has already been shown that by means of a north and south fault the western boundary of the igneous mass of Rhobell-fawr abuts on the Lingula flags about half a mile east of Moel-Hafod-Owen where *Lingulella Davisii* is plentiful. On the north the ordinary banded Lingula flags with L. Davisii and other fossils are found in the tributary brooks that run into the Mawddach, and also on the road between Abergeriw-bach and Rhiw-felin, where the black slates that constitute the upper part of the Lingula flags come on. In this area, on the banks of Afon Geirw it is certain that the slate *underlies* the volcanic material and is only exposed by denudation, while here and there dykes cut across the Lingula flags into the igneous mass above. This superposition is further proved by the outlying greenstone patches of Moel-gron on the east of Rhobell-fawr, and Craig-y-Dinas a little north of the Mawddach, and it is therefore evident that the mass once spread further to the east, and also entirely across the valley of the Mawddach to Craig-y-Dinas, and doubtless far beyond before it was partly removed by denudation. It is therefore obvious that the rocks crossed by the section between Y-Dduallt and Craig-y-Dinas were also covered by the breccias and greenstones before it was removed by denudation (see No. 3., pl. 28, and map). Wherever the water gullies on the north that intersect it show sections of the Lingula flags, the slate under-

neath is broken, crushed, and crumpled in a remarkable manner as shown in Fig. 15, p. 55. The black slaty shales and dark blue slates on its eastern boundary here contain *Lingulella Davisii* and seem to dip under the mass of Rhobell-fawr all the way from Moel-gron to Caer-hedydd, and but for the western fault causing the slates to abut on the brecciated mass, it seems not improbable that the Lingula flags would be found to crop from under it, and that, in fact, beneath it, east of the fault they actually lie in that position.

But though the black slates of the upper Lingula flags with fossils *dip* under the igneous mass of Rhobell-fawr on its eastern edge, and though they partly pass under it on the north, it is seen that the lower banded Lingula flags between Aber-geirw-mawr, and the black slates of Rhiw-felyn dip easterly at angles of from 10° to 20° in ascending order of succession, all apparently passing with their southern strike under the mass of Rhobell-fawr, the rocks of which, partly an ashy breccia ejected from a volcanic vent, lie unconformably on the denuded edges of the strata of the Lingula flags. This is quite contrary to our experience of the neighbouring felspathic ashes of Arenig and Moel-llyfnant, which not only lie above the Tremadoc slates, but are interstratified among higher slaty strata of the Arenig series. If the rocks of Rhobell-fawr were injected more or less between the beds, as I supposed when the first edition of this book was published, this difference in the mode of occurrence *of the two sets of igneous rocks* would be easily explained, but both being partly formed of ashes and breccias, the case is different, for the evidence derived from the above description would seem to show that the Rhobell-fawr breccias were laid down after the deposition, disturbance, and partial denudation of the Lingula flags, but before the deposition of the other ashy beds which are found intercalated among the Arenig strata, and never lie directly on the Lingula flags in any part of North Wales from Moelwyn to Cader Idris, *unless they possibly do so for a short space between the west flank of Y-Dduallt and the country about five miles further south near Caer-hedydd.* This may, however, be deceptive and due to a fault.

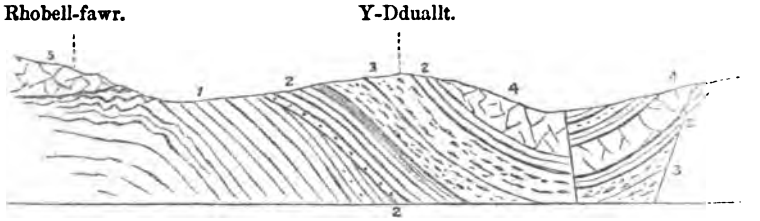
The question to a great extent now resolves itself into this:—Have there been in this neighbourhood volcanic eruptions of two periods, one long before and one after the beginning of the deposition of the Arenig grit and slates? That the Rhobell-fawr breccias are not of Lingula flag age is evident, for they lie transgressively on their denuded edges. The Tremadoc slates, which everywhere seem to lie quite conformably on the Lingula flags, are nowhere found in contact with, and passing under the mass of Rhobell-fawr. A point is thus raised whether or not in and for some distance around the area now occupied by Rhobell-fawr, a partial disturbance of the strata may have taken place in the first expansive efforts of the underground melted matter to break to the surface, and as a consequence, a local upheaval of the Lingula flags and Tremadoc slates took place, thus forming an island which suffered for a time marine and sub-aerial abrasion, so that

when in the same area a centre of open eruption was established and in action, the ashes were spread over the denuded edges of the Lingula and Tremadoc strata, while they were still above the level of the sea.

We may also consider that before this eruption took place the Arenig grit and slates were being deposited not far off, while the island still remained above water, and under these circumstances it might possibly happen that a local unconformity took place between the Tremadoc slates and Arenig beds over a considerable area. In among the sediments that formed these Arenig slates after the eruption began, ashes were being deposited at the same time that they were also spread over the previously denuded edges of part of the Lingula flags and Tremadoc slates,[5] and for this very reason it might also happen *that the ashes themselves for a space might overlap the edges of the Arenig slates and grit*, and lie directly on the slightly inclined and denuded edges of the Tremadoc strata or even on the Lingula flags themselves.

Under these circumstances, after the disturbances and denudations that produced the present form of the ground, the grit would crop directly or nearly directly from under the ashes at Y-Dduallt, as in Fig. 18.

Fig. 18.



1. Black Lingula flags.
2. Arenig grit and slate.
3. Felspathic ashes.
4. Felspathic porphyry.
5. Volcanic rocks of Rhobell-fawr.

From thence further south, the same grit may crop up against the base of the ashes, near Nant Craig-Aderyn and Moel-caer-defaed, and for two miles further south, for it is nowhere to be found in that area till we reach the ground near Maes-gwyn where it again appears for about a mile. If this is not the true explanation, then its disappearance must be accounted for by a north and south fault, between the ground half a mile N.W. of Y-Dduallt and the road half a mile east of Ystum-gwadnedd.

Other stratigraphical evidence bearing on the question is, however, not altogether wanting. Under Moelwyn the Arenig grit is about 750 feet below the interbedded felspathic porphyries and ashes, and at least 2,000 feet above the topmost beds of the Lingula flags. Further east it lies at about the same depth beneath these volcanic rocks and only about 900 or 1,000 feet above the top of the Lingula flags near Llyn Morwynion. West of Llyn Conwy the grit is only about 400 feet beneath the volcanic ashes, where the Tremadoc slates are cut out by a north

and south fault, but further south, north-east of Llyn Treweryn, the thickness of the Tremadoc beds between the black slates of the Lingula flags and the Arenig grit seems to be about 950 feet. Five miles further south, near Ffald, the thickness exposed of the Tremadoc slates seems to have diminished to about 500 feet, while the distance between the grit and the overlying ashy beds is much diminished, and continues still further to decrease to the neighbourhood of Y-Dduallt, where the grit ends to the south in the moorland valley that lies between Rhobell-fawr and the felspathic ashes on the east. The last place, proceeding south in this neighbourhood, where Tremadoc slates have been detected with certainty, is by the road close to the confluence of Nant-yr-helig and the Mawddach a little south of 'Rallt-llwyd.

It thus seems that the Tremadoc slates between the flanks of Moelwyn and this region gradually diminish in thickness, and this can only be caused by an actual thinning out of the whole mass of the Tremadoc beds, *or else by an overlap or unconformity of the Arenig grit across the upper part of the Tremadoc strata*, for there is no reason to suppose that it is due to a number of undiscovered faults. In like manner, the porphyries and ashes going east and south from the neighbourhood of Moelwyn gradually approach more and more near to the grit, till it disappears near Y-Dduallt. This disappearance of the grit might possibly be explained by a fault throwing the ashes down on the east, thus cutting out the feeble remains of the Arenig slate and the underlying grit, but considering the gradual thinning out of these slates from north to south it seems to me to partake more of the nature of a low unconformable overlap.

I have nothing further to add to this view of the subject. Readers may make their choice between it and the alternatives I have placed before them, one of which is that the volcanic breccias of Rhobell-fawr, unlike the ashy beds a little to the east, were deposited before the deposition of the Tremadoc slates. Another view of the subject is Mr. Ward's (Chap. 7). If, as I have supposed, the reason why the breccias of Rhobell-fawr lie directly on the Lingula flags is, that the Lingula flags and Tremadoc slates of this area were locally disturbed and denuded before the deposition of the Arenig grit and slates, then it may well be, that these breccias were deposited on this elevated area contemporaneously and continuously with the ashes that lie beneath the porphyry of Y-Dduallt and the other ground further east. Long after, renewed disturbances of late palæozoic date and subsequent denudations even now progressing separated the igneous masses from each other as shown in Fig. 18, by the intervening strata that separate Y-Ddualt from Rhobell-fawr.

If, as is possible, the Arenig grit and overlying strata lie really unconformably on the Tremadoc slates, this, in a palæontological point of view, may have a large significance in connexion with the local absence of certain formations as shown in Chap. 27.

CHAPTER XI.

The Igneous Rocks and associated Strata between Llyn Conwy and Manod-mawr, North of Ffestiniog.

General Description.—We have now reached an area so shattered by faults that it is impossible, without names for each stratum, to convey by writing any clear idea of the relations of all its parts, although on the ground, after much labour, it is practicable to understand these relations with precision. Bounding the Cambrian rocks on the east, there is a large fault, already mentioned, p. 20, which, passing near Trawsfynydd and Ffestiniog, cuts across the felspathic rocks north of the Ffestiniog syenite, and is lost in the slaty beds beyond (Maps 75 S.E. and N.E.). It is east of the northern part of this dislocation that the shattered country lies, and the reason why so many cracks and shiftings occur in so small an area is probably the sharp bend in the strike produced by those forces that contorted the rocks of the country. They lie, so to speak, in a corner, and the wrenched and crushed strata have been so much fractured that, as in the case of the Bala beds, north-east of Bala, fragments of the country occur here and there dropped in between enclosing faults in the most unexpected situations.

All the rocks of this complicated area belong to the horizon of the igneous rocks and the slaty series already described.

About 5 miles east of Ffestiniog, where the road branches to Penmachno and Ysptty Evan, a fault strikes northerly, following the course of the valley of Caregog, where it is cut off by the Penmachno fault. It is also a lode, and may be distinctly traced in a series of old workings from Ffynnon Eiddew to Caregog. In several places it is of very great width and solidity, being composed of a kind of cherty felspathic substance mingled with quartz not unlike some of the rocks of Paris mountain in Anglesey. The rocks of the country are thrown down on the west by this fault and repeated on a large scale. The fracture is itself well seen in the shattered lode-stuff in the brook near Hafod-y-wededd. On its opposite sides the different kinds of strata are readily distinguishable, those on the east being light grey, hard, and banded with gritty layers, like much of the true Tremadoc slates of Ffestiniog and Dolgelli. Above these and well seen on the cliffy ground a little north of Hafod-yr-edwedd, the usual dividing Arenig grit occurs overlaid by the Arenig slates which in their turn dip beneath the felspathic ashes of Llyn Conwy (*see* Diagram No. 20, p. 79). West of the fault, the lithological character of the strata is different, being dark blue and exclusively slaty as is usual with the lower portion of the Bala and the Llandeilo beds, to the latter of which they probably chiefly belong. Here and there small openings have been made, with the view of quarrying for slate.

Large masses of solid felstone marked by contorted lines of viscous flowing, and of well bedded ashes form the ridges of

Y-Garnedd and Y-Gamallt,* and rising as they do from beneath the beds on the west side of the Ffynnon Eiddew fault, it is evident that they bear the same relation to these rocks that the igneous masses of Arenig and Llyn Conwy do to the equivalent strata elsewhere. The same is the case with the igneous rocks of the Manods and of the two Moelwyns near Ffestiniog. The whole of the igneous series between Llyn Conwy and the Manods has, in fact, been repeated again and again by faults. South of the Moelwyns and of Garth on Traeth-bach, the grit so frequently mentioned forms the base of the Arenig slates, the underlying strata from thence to the grits of the Cambrian strata consisting of the Tremadoc, Lingula, and Menevian beds of the neighbourhood of Maentwrog and Traeth-bach.

A complicated series of faults intersect the country near the turnpike road between Pont-ar-afon and Ffynnon Eiddew, occasionally throwing the Arenig beds against Tremadoc slates. Two of these coalescing, pass north-east from the neighbourhood of Llyn Morwynion towards Ffynnon Eiddew.

A little south of this dislocation (which may be termed the Cerig-y-lladron fault) three others occur. One of them is probably a continuation of the Ffynnon Eiddew lode, and another of the lead lode of Cerig-y-lladron, and among them they let in two patches of solid felspathic ashes that form the broken rocks of Bryniau-fonlle and Cerig-yr-iwrch.† The latter is overlaid by a small triangular space of Upper Arenig beds; the former is profusely intermingled with irregular interstratifications of slate. They represent alike the ashy beds of Llyn Conwy and Meignint and the lower part of the rocks of Y-Gamallt.

The rocks that constitute the higher part of the ridge of Y-Garnedd and Y-Gamallt, though somewhat faulted, are continued by Llyn-y-gors and Llyn-y-ffrith-graig‡ to Tan-y-rhiw, where they are cut off by the Machno fault They consist in great part of massive blue felspathic porphyries, which, especially on Y-Gamallt, have all the slaggy appearance of rocks that have flowed along in a viscous state. Nevertheless, in this particular area there are the same difficulties to contend with that beset the geologist in his endeavours to disentangle the various species of igneous rocks on Arenig. From several points of view it presents a largely bedded aspect, but it is certain that the seeming beds are joints and planes, similar to those that occasionally puzzle the geologist on parts of Cader Idris, or on Careg Aderyn, where the rock is true felspathic lava. Cases indeed occur, although rarely, when even those who have devoted years to the study of such rocks find themselves at a loss to determine the distinction between true felspathic lavas and felspathic dust, to which pressure, and that kind of consolidation in part consequent on internal decomposition and re-formation of new silicates, have imparted a hardness, solidity, and homogeneous character equal to that of the melted porphyry itself.

Round Llyniau-y-Gamallt, and northwards from these lakes to the Machno fault, beds of undoubted ashes underlie these rocks. They are sometimes porphyritic, often largely conglomeratic or brecciated, and frequently interstratified with lenticular layers of beds of Arenig slate. A striking example of volcanic conglomerate occurs near the south end of the larger lake of Y-Gamallt. Both ashes and overlying porphyry are cut off on the north-west in the valley by the Machno fault, which throws part of the Upper Arenig slates against the igneous rocks in a similar manner to what takes place in the prolongation of the same dislocation a mile lower down the river at Caregog.

On the east side of Manod-mawr§ there is a long fault that bounds the volcanic rocks, and possibly passes north through Cwm Penamnen and

* Three miles and a half north-east from Ffestiniog.

† Three and a half miles from Ffestiniog, a little north of east.

‡ One mile and a half from Llyn Conwy, a little south of west.

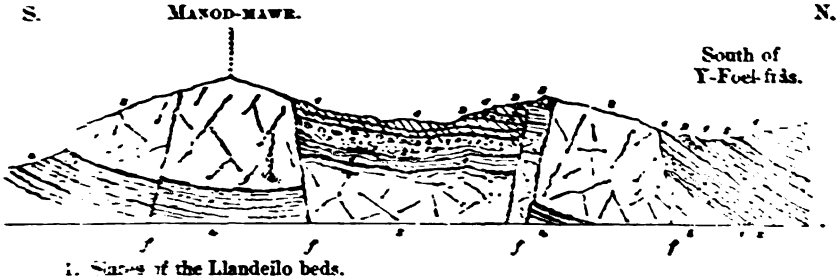
§ Manod-mawr lies 2 miles N.N.E. of Ffestiniog.

Dol-yd-delan to Llyn Geirionydd, about 2 miles west of Llanrwst.* It is a downthrow on the east. The structure of the country on its west side is comparatively simple. I shall first describe it, and then apply the knowledge thus gained to the explanation of part of the more broken ground on the east.

Manod-mawr, Manod-bach, Llyn Conwy, &c.—A north and south section from the neighbourhood of Y-Foel-frâs, by Llyn-bywydd, across Manod-mawr, exhibits, in descending order, the following arrangement:—

Fig. 19.

SECTION FROM Y-FOEL-FRÂS ACROSS MANOD-MAWR.



1. Slates of the Llandeilo beds.
1 and 2. Felspathic ashes and conglomerate, interstratified with Arenig slates.
3. Felsitic porphyry.
4. Lower Arenig slate and grit.
f. Faults.

South of Y-Foel-frâs dark upper Arenig slates, No. 1, dip north, and these are succeeded by several ashy beds, No. 2, which are interstratified with other beds of dark blue Arenig slate. The pools of Llyn-y-Drumboeth and Llyn-bywydd lie chiefly in hollows occupied by this slate, which is quarried at Cwt-y-bugail, and is the equivalent of that in the quarries a little further west. A mass of brown grey ash dips north into the lake. It is highly porphyritic, with numerous crystals of Orthoclase? felspar. The adjacent ashes are very conglomeratic, felspathic and slaty fragments being agglomerated in a mixed slaty and ashy matrix. They are remarkably inconstant, slates and ashy beds wedging out, disappearing, and again thickening, in a manner that shows great irregularity in their original accumulation. Passing westward these ashes gradually diminish in thickness, and the uppermost bed thins almost entirely away in the slate quarries, about half a mile west of Llyn-y-Drumboeth, where it is exceedingly talcose, and contains numerous crystals of iron pyrites, and in these respects strongly resembles the talc schist of Dol-y-frwynog, already described. In proportion as the ashy beds thin out the beds of workable slate thicken and improve in their westward strike. A little south of Llyn-bywydd, a north-east, and an east and west fault throw a part of these beds against a mass of felspathic porphyry (No. 3). These ashes and slates, before the denudation of the country, once spread across the Manods, from which position they have been dovetailed into the midst of the felspathic porphyry, by two principal east and west faults that cross Manod-mawr, and gradually approach each other till they coalesce and abut on a north and south dislocation that skirts Manod-bach on the west. This clearly accounts for the presence of that coating of slate and ashy bands in Fig. 19 that lies in the elevated hollow north of Manod-mawr, in the midst of which slates are now largely quarried. These rest on thick beds of volcanic conglomerate and porphyritic ashes (No. 2), that crop from under this slate on its western edge, and barely casing the surface, undulate down the inclined rocky slopes to Tan-y-Manod in a triangular space bounded by the faults above described. The slaty beds on Manod-mawr are of no great thickness, and at all points underneath them the conglomerate may certainly be found, but to determine its actual depth would require the construction of a section on a true vertical and longitudinal scale. The conglomerate is the equivalent of that which strikes south-west from the outflow of Llyn-bywydd. In both localities a band

* Maps 75 N.E. and 78 S.E.

of slate underlies it, patches of which, too small to map, are here and there exposed by denudation amid the rocky mounds between the faults immediately north of the Manods. The felspathic porphyry (No. 3) lies beneath, and where affected by faults the ashes and slates are thrown against it in the manner shown in the diagram.

The porphyry of the Manods is massive, and consists of small crystals of felspar set in a blue felspathic base, which in places become so dark and hornblendic-looking that the rock might almost be termed a greenstone. It is probably about 1,500 feet thick. The slaty band below in immediate contact with it has been altered by heat, but that above is altogether unchanged, proving the porphyry to be part of an old lava-flow. Beneath the dark altered slate on which it rests, are beds of slaty and somewhat sandy flags of the Arenig beds, below which the Arenig grit may be indistinctly traced from the west, overlying Tremadoc slates (No. 4). In these Mr. Salter found *Calymene*, *Asaphus* and other Arenig fossils.

Position and fossils both indicate that these beds are the equivalents of the Arenig slates of Tai-hirion, and the grits of Carnedd Iago and Garth, and like them they also prove that the igneous rocks of the Manods and Moelwyns were ejected during the deposition of the Arenig or Lower Llandeilo beds of Murchison.

The Dolwyddelan and Manod-mawr fault cuts off the Manod rocks, so that the equivalents of the Arenig beds and ashes of Llyn-bywydd and Manod-mawr are thrown down on the east. This accounts for their position so far south, for they once covered the neighbouring lower rocks, till removed by denudation. The slate quarries in the beds interstratified with ashes that are enclosed between the minor north and south faults that include Bwlch Careg-y-frain are therefore the equivalents of the southern part of the slate quarries west of Llyn-du-bach. They dip north-west at a low angle. Two faults branch off from that of Manod-mawr in Cwm-tegwel, and another zig-zag crack unites them north of Hafod-Yspytty. The latter is a downthrow on the north, and the porphyry that is here enclosed in the triangular space between three faults is equivalent to that of the Manods. The dislocation that skirts the south-east base of Manod-mawr is a downthrow on the north-west, throwing the Manod-mawr porphyry against Tremadoc slate. Two miles E.N.E. from Ffestiniog, the Roman road crosses the brook at a ford called Rhyd-yr-Helen. From this point a fault strikes N.N.E., and joins that of the Machno near Rhiw-bach. The rocks are thrown down on the east, and the concentrically arranged beds of slate and ashes about half way between Manod-mawr and Llyniau-y-Gamallt are the probable equivalents of similar interstratifications about a mile further north. Another fault passes from near Moel-machyrig and west of the Gamallt lakes to Craig-y-gareg-lwyd above Llyn-y-Morwynion,* where it branches into many dislocations too numerous to define on the map. This may be termed the Gamallt fault. Between these two main faults west of Llyniau-y-Gamallt the rocks roll over in an anticlinal curve faulted on its east side, and the ashy and slaty layers of Llyniau-y-Gamallt are the equivalents (changed in lithological composition) of the lower part of the workable slates north of Manod-bach. Several easterly dislocations pass between the Rhyd-yr-Helen and Llyn-y-ffrith-graig faults. The principal of these passes E.N.E. from Rhyd-yr-Helen in the direction of the Gamallt fault, which it joins a little south of the stream that rises in the lakes. It is a downthrow on the south, and all the ashes, slates, and felspathic porphyries that lie between it and Careg-lwyd are the equivalents again repeated of similar interstratifications lately described. Some of the slates have been quarried. They dip east and north-east. It is even possible that one or more of the porphyries of the area represent on a smaller scale the greater porphyritic masses of the Manods and of the block of country above Hafod-Yspytty. The rocks of Y-Garnedd and Careg-y-foel-gron belong to the same set. Other more marked dislocations occur in the immediate neighbourhood. On the summit of Y-Garnedd the word *smashed* is the only term that expresses the state of the country, veins and branches of quartz confusedly intermingled with slaty matter ramifying in all directions over a broad space for nearly a quarter of a mile.

* Three miles south-west of Penmachno.

The general effect of the tangled maze of faults north and north-east of Ffestiniog is that the Llyn-bywydd slate rocks* and ashes and their equivalents at the slate quarries near Llyn-y-drumboeth are thrown down so as to form the hills that overlook Llyn-y-Morwynion about 2½ miles to the south. The ashy and slaty beds, which are associated with the slates near Llyn-y-drumboeth and Llyn-bywydd are by these faults repeated, first, on the Manrods, next in and around the quarries immediately north of Bwlch-Careg-y-fran, and again further south on the east side of Sarn Helen; and not only are the slaty beds that are interstratified with the ashes smaller in quantity and otherwise deteriorated, but near Rhyd-yr-Helen various minor beds of more solid porphyries are associated with them, in part equivalent to the great porphyritic masses of the Manods. The following diagrams will help to explain the structure of this difficult country between the Manods and the Llyn Conwy and Migneint ashes, —an area so perplexed and intricate that it is almost impossible for any one to comprehend its details who has not, like Mr. Aveline and myself, mapped each one of its component beds.

Immediately north of Llyn Conwy, an east and west line between Fridd Pen-y-fedw and the slate quarries near Tan-y-rhiw,† gives the following section:—

Fig. 20.

East and West Section North of Llyn Conwy.

1, 1′, and 1″. Upper Arenig slates.
2. Felspathic ashes.
2′. Felspathic porphyry.
3. Arenig beds, &c.
4. Arenig Grit.
5. Tremadoc slate.
f. Faults.

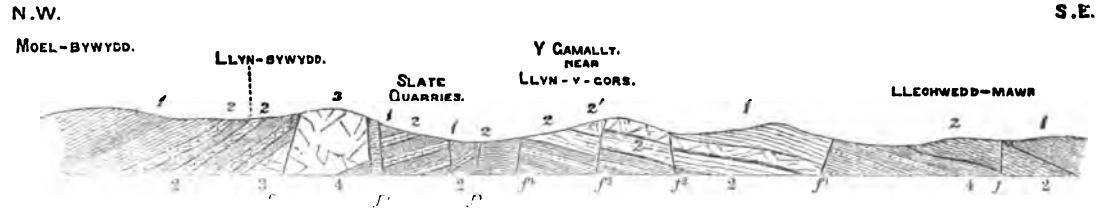
No. 1 represents the dark blue Arenig slate that rests on the igneous rocks all round the great Merioneth anticlinal, 1′ the repetition of the same set of rocks by the Ffynnon Eiddew fault which is well seen in the lode-stuff in the brook near Hafod-y-wededd, No. 1′ is the equivalent of the Arenig beds near Tan-y-rhiw on the north-west side of the Penmachno fault *f*. No. 2 represents the felspathic ashes of Llyn Conwy, and 2′ a part of the equivalent rock of the Gamallt range. No. 3 indicates the Arenig slate, and 4 the grit underneath the Arenig slate and ashy beds 2, and the lower strata 5 form an upper part of the Tremadoc slate. The whole *country* is thus repeated by the Ffynnon Eiddew and Caregog fault marked *f**.

The same rocks show the following more complicated arrangement on a north-west line from the slate at Llechwedd-mawr, half a mile east of Cerrig-y-lladron‡ to Moel-bywydd north of the Manods.

* A mile and a half north of Manod-mawr.
† About 5 miles north-east of Ffestiniog.
‡ About 6 miles from Ffestiniog, a little north of east.

Fig. 21.

SECTION FROM LLECHWEDD-MAWR, SOUTH OF LLYN CONWY, TO MOEL-BYWYDD, NORTH OF MANOD-BACH.



No. 1 represents the Upper Arenig beds near Cerrig-y-lladron (a little south of the river Conwy), and the same slates near Y-Gamallt, and at Moel-bywydd.

No. 2. The ashes of Llyn-Conwy with interstratified Arenig slates and their equivalents north of Llyniau-y-Gamallt, near Bwlch-Careg-y-fran, and by Llyn-bywydd, near the slate quarries. No. 2′ is part of this series, and represents the felspathic porphyry of Y-Gamallt.

No. 3. Part of the Manod porphyry, about a mile north of the trigonometrical station on Manod-mawr.

No. 4. The Arenig slates and underlying grit.

The letter *f* shows the position of a small fault that slightly affects the junction of the Arenig beds and ashes near Cerrig-y-lladron, and f^1 the effect of the Ffynnon Eiddew fault, repeating the upper Arenig beds and the underlying igneous rocks. f^2, a small downthrow on the south-east near Llyn-y-gors; f^3, another on the north-west; f^4, three faults, throwing in small sections of the Arenig beds and thin bands of ash, &c.; f^5, the faults immediately east of Manod-mawr, throwing down the ashes and slates of the Arenig beds on the east; and f^6, an east and west fault near Llyn-y-bywydd, throwing dow on the north interstratifications of ashes and slate (Upper Arenig beds) against the Manod porphyry.

The whole country illustrated by this diagram lies in the form of a much faulted anticlinal curve, the ashes of Llyn-bywydd, Llyniau-y-Gamallt, and Cerrig-y-lladron being identical, although there are considerable variations in the nature of some of their associated beds. Thus the ashes of Y-Gamallt, like those of Llyn-y-drumboeth, are interstratified with slates; but, while there are great and profitable slate quarries near the latter place, near Y-Gamallt, the equivalent slaty bands in the ashes are more short and irregular. The ashy bands have thickened, and the slaty beds in general have thinned. The rocks of Llyn-Conwy and Cerig-y-lladron exhibit a still larger development of the same igneous material, forming a thick solidly bedded mass of felspathic porphyritic and brecciated ashes, sparingly intermingled with short lenticular bands of slate. The felspathic lava beds have also their rapid variations, and though some of the bands near Llyn-y-Morwynion may represent the Manod porphyry, there is no trace of porphyritic lava at Llyn Conwy and Cerrig-y-lladron. The trap that overlies the ashes on the Gamallt range is absent above the ashes of Llyn Conwy and Llyn-bywydd, at the opposite ends of the anticlinal curve.

The great mass of the Manod porphyry might be supposed to be an intrusive boss, especially as (eliminating the faults) it thins away so rapidly both to the east and west. Nevertheless, it decidedly underlies unaltered slates and ashes, and overlies altered Arenig beds, and altogether it maintains so regular a horizon, and otherwise so behaves in connexion with the faults, that all the evidence is in favour of its non-intrusive and interbedded character. This probability is not diminished by the circumstance that between Cerrig-y-lladron and the Arenigs there is a mass of porphyry similar in lithological character to that of the Manods, and occupying the same position between the ashes and the underlying fossiliferous strata.

Its disappearance between Llyn Serw and the Manods is no proof that the masses are not equivalent and contemporaneous, for the original edges of the lava currents might be so irregular, that we must not expect to find them cropping out everywhere from beneath the overlying ashes, which, as originally deposited, may in places have overlapped their edges. If this be so, then the porphyry may spread northward from Llyn Serw deep under ground, in such a way that before the faulting and denudation of the country it was continuously connected with the porphyry of the Manods.

Many of the faults in the area above described, between the Llyn Conwy ash and the Manods, are also lodes; and one of these, at Llechwedd-mawr, was worked for lead. The fault that runs north from Ffynnon Eiddew is a broad lode, chiefly filled with quartz and a kind of hard cherty matter. In places it has been worked for manganese. On a broad space on the top of Y-Garnedd the rocks have been much dislocated, and the dislocations are entirely filled with quartz. The south-west lode at Rhyd-yr-Helen yields a little copper pyrites. The north and

south lode west of Llyniau-y-Gamallt was formerly worked for lead, and several others round the Manods yield small quantities of that mineral mixed with quartz with which the lodes are chiefly filled. It is said also that traces of gold have been found in lodes north of these mountains. I am not aware that any of the lodes have been worked profitably for many years.

CHAPTER XII.

The Menevian Beds and Lingula, Tremadoc, and Arenig Slates between Rhobell-fawr and Criccieth.

General Description.—North of the great mass of igneous rocks that form Rhobell-fawr the Mawddach flows from east to west. Between this river and Traeth-bach* the fossiliferous strata above the Cambrian grits preserve the same character that they possess on the shores of the estuary between Barmouth and Dolgelli, and the fossils of the Lingula flags are the same, *Lingulella Davisii*, *Hymenocaris vermicauda*, *Paradoxides Davidis* and *P. Hicksii*, *Olenus micrurus*, *Agnostus princeps*, and *Cruziana*, with many other obscure forms. (Plates 2, 3, and 4.)

The Tremadoc slates and Arenig beds are well known on the flanks of Cader Idris and the Arans. On the northern curve of the great Merionethshire anticlinal the same assemblage of forms was found by Messrs. Salter and Homfray, along a range of more than 20 miles between Taihirion and the neighbourhood of Criccieth.

The whole series down to the Cambrian grits is pierced by numerous dykes and masses of greenstone, but no contemporaneously interbedded porphyries or ashes are associated with the Tremadoc slates, Lingula, and Menevian beds here or elsewhere in North Wales.

Lingula Flags, &c.—For five or six miles north of Rhobell-fawr the Lingula flags and Tremadoc slates, with various undulations, dip more steadily eastward than in the slaty ground that borders Rhobell-fawr on the east. On the east side of the Ffestiniog and Trawsfynydd fault the Menevian beds are thrown down out of sight, the effect being that excepting at the southern end of the fault, the Lingula flags abut on the Cambrian grits. They chiefly consist of grey slate, sandy flags, and grits, associated with dark blue or black slates. Good examples of the more sandy beds, sometimes ripple-marked, may be seen on the banks of the Mawddach and on the hills north and north-west of Craig-y-Dinas. The boundary between the Cambrian grits and the Silurian rocks runs by the beautiful waterfall of Rhaidr Mawddach, where, however, the rocks are so much fractured and confusedly intermingled with greenstones, that it is impossible to say whether or not the very lowest beds join the Cambrian strata. They are, however, very low in the series, seeing that a little further south of the grits of Craig-y-Penmaen, the Menevian beds regularly overlie the Cambrian grits. In this neighbourhood one trilobite, *Paradoxides Hicksii*, for some time called *Forchammeri*, was found by Mr. Selwyn near the gold mine in Cwm Eisen, and numerous specimens of *Lingulella Davisii* (Pl. 2) occur in the banded grits and slaty Lingula flags south-west and north-west of Craig-y-Dinas and Gallt-y-Daren. The general

* Map 75 N.E. and S.E.

arrangement of these fossiliferous strata on Bryn-pig, and from thence to the Cambrian rocks near Trawsfynydd, is well expressed in the Section, Pl. 28, No. 3. Further north the whole series between the Cambrian grits and the ashes, and felspathic lavas of the Arenigs occupy a wider space, rising and falling in anticlinal and synclinal curves in the country watered by the rivers Gain and Prysor, and two small bosses of Cambrian rocks reach the surface by a combination of curves, faults, and denudation. The larger patch is a mile and a half in length and from a quarter to three quarters of a mile in width. On the north and east the Menevian beds are believed to rest on it at angles of about 18°; on the south and west the Lingula flags are faulted against it. The smaller patch lies about three miles E.N.E. of Trawsfynydd near Castell-y-Prysor. On the east the Menevian beds rest on it at angles of about 30°, and, like the larger boss, it is also bounded on the south and west by faults. Notwithstanding these disturbances, south of the river Prysor the general inclination is eastward, but, beyond, the rocks begin to dip to the north-east and north, following, between Ffestiniog and the sea, the strike of the great anticlinal curve in its course towards the west.

It is in the immediate neighbourhood of Trawsfynydd that the dome-shaped Cambrian strata curve round to the west; for, while near the Trawsfynydd fault they strike nearly east, abutting on the Lingula flags, further west on the crags of Diphwys, and Y-Graig-ddrwg, they assume a north-east and south-west strike, and dip towards the Silurian strata of Traeth-bach and Morfa Harlech.

West of Craig-das-eithin* the Lingula beds form a synclinal curve. The Cambrian rocks do not, however, crop from beneath their western margin, for the Trawsfynydd and Ffestiniog fault by a downthrow on the east, cuts out both the Upper Cambrian beds and the Menevian strata, so that on the east side of the great anticlinical, the apex of which lies south-west of Trawsfynydd, only about 1,800 feet of the Cambrian beds, roll towards the adjoining Lingula flags. The throw of the fault, therefore, near Trawsfynydd, cannot be less than about 2,400 feet. The evidence of the fault is perfect, since both formations yield a sufficiency of dips, and are seen to strike directly at each other. In many places along the road between Trawsfynydd and Ty'n-y-nant the Cambrian grits rise in thick shelving beds that dip a little to the west of north, at angles varying from 10° to 25° and rarely 40°.

Near Ffestiniog there are numerous Lingulellæ in the grey ripple-marked flaggy and gritty bands in the river above and below Rhaiadr Cynfael, which, together with similar rocks near the town, are the general equivalents of the fossiliferous strata of Bryn-pig, and Gallt-y-daren about two miles west of Moel-llyfnant. On the same side of the Ffestiniog fault, further north, and a little higher in the series between Ffestiniog and the stream under Pengwern, the Lingula beds are fine grained, and somewhat spotted, talcose, and flaky, and these, in ascending order, pass into the hard speckled beds (afterwards to be described) that occupy about a mile of country west of Manod-bach and south of Careg-du two miles north of Ffestiniog.

Good sections of a high part of the Lingula flags occur further east near Llyn Treweryn, and in spite of the glacial drift occasional patches of rock are exposed in Nant-y-lladron, Nant-y-groes, and on the shores of Llyn-y-dywarchen.† They consist generally of thin grey slaty beds, flags, and grits. Like those of Dolgelli, the uppermost slates are almost black round Llyn Tryweryn and in the bed of the brook towards Moel-llyfnant. In these strata *Lingulella Davisii, Obolella sagitalis, Orthis lenticularis* and *Olenus serratus* were found in 1875 by Mr. Homfray, Mr. Etheridge, and myself, and the whole are more or less pyritous. This special band of black slaty shale divides the more flaggy Lingula beds from the Tremadoc slates, and has been noted by Mr. Homfray in the same stratigraphical position, following the general curves of the great Merionethshire anticlinal all the way from the rocks south of the estuary of the Mawddach to Ogof-ddu near Criccieth. The list of fossils from these subformations is given in the Appendix pp. 348, 349. At Llyn-y-dywarchen I found *Lingulella Davisii* in sandy flags with wavy rippled surfaces, and also in similar strata mingled with dark slates by Pont-y-lladron, Mr. Salter found numerous

* About 2½ miles S. E. of Trawsfynydd.

† About 6 miles east of Ffestiniog.

specimens of the same shell accompanied by ripple and Annelid markings. A little east of the bridge there are two quarries of thin bedded dark grey flaggy rocks, containing a small variety of *Lingulella Davisii* and Annelid marks:* and both occur in the slaty beds beneath the grit, about a quarter of a mile west of Carnedd Iago, a little north of the Ffestiniog and Bala road.

In this locality by Pont-Nant-y-lladron it is certain that between the Lingula flags and the Arenig grit there is no room for anything like the thickness of Tremadoc slate that exists further west towards the Manods and Moelwyn. There are some symptoms of a possible fault just by the bridge on the turnpike road, but it is very uncertain, and if as is likely there be no important fault, then either the Tremadoc slates must have very rapidly thinned away, or else the grit that lies at the base of the Arenig beds must have overlapped the upper part of the Tremadoc series in an unconformable manner.

Many parts of the Lingula flags east and south-east of Ffestiniog are pierced by masses of greenstone, all much smaller than the broad-spreading rocks of Rhobell-fawr. They are especially numerous in the district between Afon Gain and the Ffestiniog and Bala road.

To describe each in detail would serve no useful purpose. The rocks in contact with them are often altered, and the greenstones have frequently been thrust between the beds. Without careful observation one might be apt to consider some of these as rising sheer through the strata, and as having a greater solid bulk than they possess. Some of them seem to be isolated sheets of greenstone resting on the slates, once connected with neighbouring masses, but since separated by denudation. Occasionally they are largely crystalline, hornblende forming the principal constituent, but in other cases (and these are generally less crystalline), they look so grey and felspathic that it is not without hesitation that they have been coloured with the greenstones, though in the very same mass these varieties often graduate into each other. The section† crosses one of the larger and more solid looking bosses at Craig-das-Eithin,‡ Fig. 3, pl. 28.

Tremadoc Slates and Arenig Beds.—The regularity of succession is somewhat interfered with by the faults south-west of Manod-bach, which for a space induce easterly dips. Between Cae-blaidd and Manod-bach, the section is however more regular, and the Tremadoc slates and Arenig beds have been detailed by Mr. Salter in the following ascending order, beginning near the top of the true Lingula flags:—

"1. Light coloured hard spotted beds.—Lingula Flags.	
"2. Spotted grey sandstones.	Tremadoc Slates?
"3. Grey sandstones indistinctly spotted.	
"4. Grey flags and granular sandstones.	
"5. Grey concretionary sandstones.	
"6. Grey sandy beds, flaky, containing *Calymene Murchisoni* and *Asaphus affinis*.	Arenig beds.
"7. Light spotted slate, and grey irregularly bedded sandstones, with numerous impressions of *Calymene Murchisoni* var. *C. parvifrons*, *Ogygia Selwynii* (Pl. 9), and *Trinucleus*.	
"8. Thin bedded flaky slate, somewhat ferruginous, containing *Orthis Calligramma*." (Pl. 22.)	

Between this and the felstone porphyry of the Manods there lies the thin slaty band already described. Between the Tremadoc and Arenig beds the boundary is here somewhat obscure, and the same is the case south of Caregdu.

Menevian, Lingula, Tremadoc, and Arenig beds, west of Ffestiniog.—In the upper Cambrian beds near Tyddyn-du, two miles S.S.W. of Ffestiniog, the texture of the strata undergoes rapid variations. Some of the beds are coarse grits, with large oval grains of decomposing felspar. This passes into fine-grained, compact, hard grits, some dark, others lighter, with disseminated flakes of slaty matter that give a streaky aspect to the rock.

* This is the place of the Tremadoc slate, but the peculiar fossils of that group occur further west.

† Sheet 29, line 1, Pl. 28, No. 3.

‡ Two miles and a half S.E. of Trawsfynydd.

A strip of soft ground that lies between the Cambrian and the lowest of the Lingula grits is doubtless occupied by Menevian beds, equivalent to those at Aber-rhamffroch near Barmouth. They are well exposed in Ceu-nant above Rhaiadr-du, somewhat more than a mile south of Maentwrog, and undoubtedly pass to the south-west overlying the Cambrian grits as far as Morfa Harlech.

Between Ffestiniog and Traeth-bach the Lingula flags and Tremadoc slates are similar to those on the banks of the Mawddach near Dolgelli. Their general arrangement is shown in Pl. 28, No. 3.* The whole country, especially north of the river, has a rough and rugged appearance, caused by interstratification of hard siliceo-felspathic with softer slaty beds, the peculiar hardness of many of the strata being due perhaps to the toughly binding character of new silicates of soda and potash formed by internal decompositions and new combinations in the body of the rock. There is a strong resemblance in the outlines of the ground, between the estuary of the Mawddach and the top of Cader Idris and that between Maentwrog and Moelwyn, owing to the nature of the rocks being nearly identical.

With the view of determining the precise palæontological succession, the sections were repeatedly examined by the late Mr. Salter, to whom I am indebted for most of the following minute detail respecting the strata between Ffestiniog and Tremadoc.

The Menevian beds are well seen on the ground near Tafarn Helig.† They are dark grey and softer than the Cambrian beds; but, like them, contain numerous angular and sub-angular grains of felspar. Other more flaggy and compact beds are associated with them, and those at the neighbouring lodge gate are succeeded by fine-grained grits that alternate with layers of thin bedded black ferruginous slate, jointed but not distinctly cleaved. A considerable thickness of black slate succeeds these alternations, and at the first sharp angle in the Avenue grits again appear, which, in their turn, are succeeded by a thick series of hard sandy grey beds, with rippled surfaces and *Annelide tracks*. Black slaty layers still occur in these, and the joints are full of oxide of iron. Above there are dark grey ferruginous slates, apparently of the Lingula flags, in which Mr. Salter found *Lingulella Davisii*, *Agnostus princeps* (Pl. 4), and *Olenus micrurus* sparingly distributed. In similar slate a little higher the surfaces are rippled, still marked by *Annelide tracks*, and full of the same *Agnostus*. Thin hard black ferruginous layers are more or less interstratified with these, good examples of which occur at Cae'n-y-coed, in the upper part of the village of Maentwrog, and at the waterfall where the beds are full of *Agnostus*.‡ This black slaty part of the series is probably about 1,300 feet thick, and occupies nearly half the ground between the Cambrian rocks and the river Dwyryd. The cleavage of all these rocks is imperfect. Overlying the black shales there is a thick series of compact sandstones as far as Maentwrog turnpike, with subordinate beds of slate containing trilobites and Annelide tracks lying about the middle of the Lingula flag series.

Higher in the Lingula series at Tan-y-bwlch there are hard flaky beds (with iron rust in the lines of cleavage), which alternate with a few thinner and more slaty beds. Similar strata occur at the west lodge of Plas Tan-y-bwlch and below Bryn-mawr, but more wavy in outline, and above them flaky beds containing small balls of iron pyrites. In the lower part of the garden quarry in front of Tan-y-bwlch Inn the layers contain *Lingulellæ* of all sizes; and the upper harder beds exhibit a few *Annelide tracks* and burrows. Behind Bryn-mawr and Tan-y-bwlch there are fine grained beds, which splinter into pencils of 8 or 10 inches in length, and contain *Annelides*, *Lingulella Davisii*, and *Cruziana semiplicata*. They alternate with thin hard bands somewhat gritty, and are succeeded by a bluish cleaved flaky slate, containing *Lingulella Davisii*, much distorted by cleavage. A well-defined set of ferruginous slates rests upon these beds and form the uppermost portion of the Lingula flags. When freshly fractured they are intensely black, but contain so much iron that its oxidation imparts a rusty hue to the rocks above the tramway, forming a distinctive and peculiar feature in the landscape, like the red hills on the

* Also in 6-inch Section, Sheet 28, line 4.

† Where the turnpike roads branch to Maentwrog south-west of Ffestiniog.

‡ Mr. Salter noticed immense quantities of *Agnostus princeps* in the rocks below the waterfall. Every flake of slate is crowded with their crushed impressions.

banks of the Mawddach near Llanelltyd and Tyn-y-groes, which however belong to a lower portion of the Lingula series. This upper black slate can easily be traced, in spite of numerous small cross faults, from the turnpike road near the quay, across the tramroad above Bryn-mawr, and through the hills behind Tan-y-bwlch by Y-Dduallt (near which they have been worked for iron) towards the Ffestiniog fault. They contain on the tramway south of Tafarn-trip,* *Dictyonema sociale*, and a species of *Conocoryphe*, probably *C. invita* (Pl. 4, figs. 5–7).

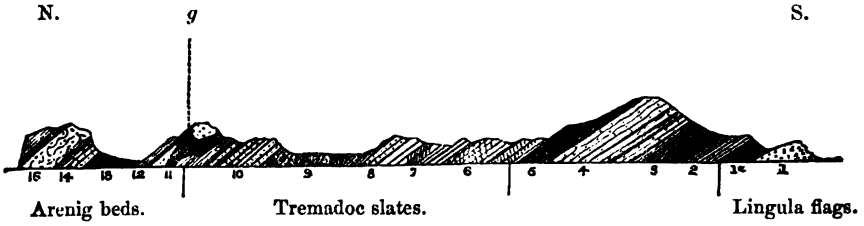
The base of the lower Tremadoc slate immediately overlies the black slaty beds described above, consisting of bluish slate, slightly ferruginous, and splitting into pencil-like fragments. It contains many small *Lingulellæ*, and is much used in the walls of the neighbourhood. A hard compact band rests on this, followed by thinner beds where the old Beddgelert road begins, above which are hard fine-grained speckled and flaky beds, which pass into hard metamorphosed felspathic-looking beds about half a mile north of Tafarn-trip. On these lie the coarse quartzose grits of Bwlch-y-Maen of considerable thickness, which separate the Tremadoc from the Arenig beds, and above this horizon the lower Arenig slate, with genuine ashy interstratifications, begins.

Many other excellent sections of the Lingula series occur on the ground between Maentwrog and Morfa Harlech. With some minor curves, they generally dip to the north-west at angles between 25° and 45°, inducing a characteristic series of sloping lines on the hills, that miles off indicate to the experienced eye the average inclinations of the strata. The beds correspond to those between Maentwrog and Tafarn-helig.

Concerning the promontory of Penrhyn between Traeth-bach and Traeth-mawr, Mr. Salter observed the following order in the strata, and constructed a diagramatic section across it.

Fig. 22.

DIAGRAM SECTION ACROSS THE PENRHYN PROMONTORY.



1. Micaceous light-coloured flaky sandstones. *Olenus Lingulella Davisii.*
1*a*. Black ferruginous slate. *Orthis, Olenus*, &c. *Dictyonema* at the top.

TREMADOC SLATE.

2, 3, 4. Iron stained dark slates, with a thick series *above* them of hard blue rock, sometimes almost massive, with occasional beds of pisolitic iron, and with many lines of felspathic matter. (A few beds of the same nature lie below the dark slates.) *Psilocephalus innotatus, Niobe Homfrayi* (Pl. 6), with small *Lingulellæ*, and *Dictyonema sociale*, are characteristic of it. [Lower Tremadoc slate.] Hills above Aber-ia, near Deudraeth.

5, 6. Slate with a pencil fracture, in thick beds, interspersed with hard, tough, and sandy layers, the same as those quarried for building at Portmadoc. *Asaphus Homfrayi* was found here (Pl. 8, figs. 11–14). The same beds rich in fossils at Tremadoc.

7, 8. Alternating series of hard bluish flat-bedded slates and pencil slate (soft slate with a double cleavage, which breaks the rock into thin pencils); fossils rare. Penamser east of Tremadoc, Penrhyn-llwyd, &c. [The iron ore occurs in this series at Tremadoc.]

9. Soft thin bedded sandy shales. Marsh opposite Deudraeth, Minffordd, &c.

10. Hard bluish flags. Garth hill, north side of west end of hill, and south side of east end, reaching to Deudraeth. Rich in fossils. See list in Appendix, pp. 358, 359. *Angelina Sedgwickii, Asaphus Homfrayi, Cheirurus, Ogygia scutatrix* (Pl. 9), *Conularia, Orthoceras*, &c., with large specimens of *Lingulella Davisii.*

* N.W. of Maentwrog.

The greenstone *g* penetrates these beds (10) somewhat obliquely, so as to lie on the chief part of them towards the east side, and under them on the west side.

ARENIG BEDS.

11. Thick grits, felspathic near the base. Garth hill; no fossils.
12. Flat-bedded iron-stained black slate. Ty-obry; full of characteristic fossils. *Calymene Murchisoni*, *Asaphus affinis* (Pl. 8), *Dionide atra*, *Æglina caliginosa* (Pl. 11), with *graptolites*, &c. See Appendix.
13, 14, 15. Fine-grained bluish black slate, succeeded by ashy slate, and this by an ash bed, follow in the marshy ground to the north, and are the equivalents of the beds of Tan-yr'-Allt, on the west side of the estuary.

In tracing out the really simple arrangement of the beds in this insulated tract of country, the presence of the peculiar band of black and ferruginous slates is of great consequence. They can be traced by short traverses from the turnpike road along its east side, in front of the hill farms of the Deudraeth. They come to the shore in considerable thickness at Abergafron, where they are highly contorted along a north and south line of fault, and, leaving the water's edge again at Borthwen-mawr continue by Castell-Deudraeth to Aber-ia, where they are cut off by faults and turn north-westwards and reach the estuary at a cave near the east end of the embankment. Here they are seen to be overlaid in the pleasure grounds of Aber-ia by the dark earthy slates, No. 3, and these again by the harder beds, No. 4.

These bluish hard beds (4), often a ribbon slate, form the ridge of the country by Plas-yn-y-Penrhyn, and through the grounds of Castell Deudraeth, &c., and then are followed in the broken knolls that range towards Minffordd, by the pencil slate and its associated harder shales. The low marshy ground is occupied by the soft shales, No. 9, but no fossiliferous beds of consequence occur till we reach the higher heathy ground of Garth hill,* though fossils are here and there met with.

Between the Ffestiniog and Trawsfynydd fault and the mouth of the estuary of Traeth-bach the strata are penetrated by numerous greenstone dykes, chiefly of a dark green colour, like the ordinary hornblendic varieties. They generally, but by no means universally, run in the line of strike, and as a rule entirely resemble other greenstone dykes in the same position on the east and south of the Merionethshire Cambrian strata.

In the area crossed by the section (Pl. 28, No. 3.),† the Menevian beds are about 225 feet thick, the Lingula flags about 4,000 feet, and the Tremadoc slates apparently about 3,000 feet in thickness, giving a total of more than 7,000 feet between the Cambrian grits and the base of the Arenig beds. The presence however of the crystalline mass of Moel Tan-y-grisiau introduces an element of uncertainty into this estimate with regard to the Tremadoc slates. The whole, with slight exceptions, dip steadily north and north-west at angles varying from 20° to 40° or 50°.

Underneath the sands of Traeth-bach the series of strata above the Cambrian grits pass into the Tremadoc and Criccieth country. But before explaining the structure of that area it will be more convenient to describe the rocks that overlie the Ffestiniog syenite and the igneous rocks of Moel-wyn and Cwm Orthin.

The syenite lies rather more than a mile north-west of Ffestiniog, and is about 2½ miles in length by nearly a mile in width. On the west it thins away to a point, and on the east it is bounded by the fault that cuts off the Cambrian rocks near Trawsfynydd. The whole forms a rocky moorland, strewn with its own fragments, and boulders (*blocs perchés*) from the neighbouring hills. It consists principally of a granular compound of orthoclase felspar, and quartz, with a sparing admixture of specks of poorly crystallized hornblende, and is by no means a fine specimen of its class. Up to its south-eastern edge the Tremadoc slates dip steadily towards it, and on the opposite side the strata seem in a measure to rest upon it, although both its nature and form preclude the idea of its being a bed of contemporaneous lava like the felspathic rocks in its neighbourhood. In some parts, too, the line of junction is broken and

* The shells and trilobites of this rich locality are noted above.

† *See also* Section Sheet 28, line 4, and Map 75 N.E.

irregular, and round its margin the stratified rocks are so highly altered that the stratified and igneous rocks seem to pass into each other. A good example of this occurs on the north of Cefn-trwsgyl, where the strata at the upper junction have been altered to the point that is difficult or impossible to define the precise limits of the stratified and unstratified material.

The rocks on the north-west and west of the syenite possess a character so singular that it is almost impossible to define them, the more so that on all sides they pass insensibly into those other varieties of stratified rocks that form the mass of the neighbouring country. As a convenient distinction in the Ffestiniog district, they were at one time called Upper Lingula flags, though in reality they belong to the Upper Tremadoc and Arenig slates. In the first edition of this book, these strata about half way between Maentwrog and Moelwyn-bach north of Llyn-y-garn, were supposed, to contain some ashy matter. A re-examination of the country in 1874 and 1875 disabused me of this idea and showed that they are simply the ordinary strata of the country much altered. Excellent sections are exposed on the hills on either side of the road leading from Tan-y-grisiau to Cwm Orthin, or from Glan-'r-afon-ddu and Ael-goch towards Llyn-trwstyllon*, but, indeed, the ground is so bare, rugged, and cliffy that almost anywhere between the Manods and the Beddgelert road, near Llanfrothen, the whole series is exposed. It is formed of beds both below and above the grit at the base of the Arenig slate, the separate strata varying from about a quarter of an inch to two feet in thickness, the thinner beds predominating. Being perfectly stratified, these rocks present a beautifully banded structure, rendered more prominent by the unequal decomposition of beds of diffent degrees of hardness. Their colour when fractured is bluish grey, curiously spotted or mottled like some honestones, or those rocks sometimes called variolite. These *pass into* a variety of rock composed of felspathic matter, speckled with hornblende (?), somewhat crystalline, but generally arranged more after the manner in which that mineral occurs in some varieties of gneiss, than in true crystalline rocks that have been melted. They cannot, however, be classed with the gneissic rocks, for this structure is exceptional, and the nature of the rocks is such, that their characteristics seem partly to belong to peculiarities of original deposition, partly to subsequent metamorphism possibly connected with the occurrence of the neighbouring syenite. Some of the beds are greasy to the touch, and in general they are very fine grained. In others the rocks are interstratified with irregular bands of blue pyritous slate; and indeed the blue muddy matter used in the formation of the slaty beds is mixed in every possible per-centage with the more felspathic substances that form the main mass of this country. Especially towards the lower beds it would be easy to collect specimens showing a perfect passage into any of the varieties of ordinary flags on which it rests.

It will be noticed that the kind of metamorphism above described is here peculiar not to the Tremadoc slates alone, but extends all the way from the south side of the Manods to the old road from Tan-y-bwlch to Beddgelert near Bwlch-y-maen, and equally affects the Tremadoc and Arenig strata Westward of this the Tremadoc and Arenig slates are comparatively unaltered below and above the long band of grit that runs from Bwlch-y-maen to the greenstone of Garth on Traeth-mawr.

It is also worthy of remark that a great change takes place in the lithological character of these rocks as they pass eastward, for their peculiarities disappear, not by the thinning out of the beds, but because they gradually lose much of their speckled appearance and pass by insensible gradations into ordinary fossiliferous grits and slaty beds. Under the Manods, however, they are still in part distinctly speckled and talcose, and indeed traces of it occur as far south-east as the neighbourhood of Nant-y-lladron.

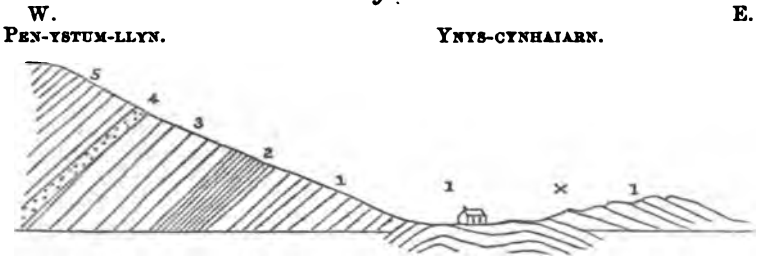
It has been shown, Fig. 22, p. 86, that the Tremadoc slates occupy the greater part of the promontory of Penrhyn Deudraeth. Further west between Portmadoc and the neighbourhood of Criccieth, the Lingula flags and Tremadoc slate form the whole of the coast, and stretch northward to Penmorfa and the grounds of

* Cwm Orthin lies 3 miles from Ffestiniog north-westerly, and Llyn-Trwstyllon close under the peak of Moelwyn on the south-east.

Brynkir. Between Criccieth and Ogof-ddu the grit, about ten feet thick, that divides the Tremadoc slate and Arenig beds runs out to sea dipping westward about 40°. From thence it strikes northerly by Drws-deugoed under the eastern end of the Dolbenmaen alluvium, beyond which it is lost under the boulder-drift and other obscurations, but it is probable that it there curves eastward, and that the grit or an equivalent line strikes from thence in a south-easterly direction to Penmorfa and abuts on the Penmorfa fault.

East and south of the grit the Tremadoc and Lingula beds lie somewhat in the form of the half of an elongated dome. The uppermost black slates of the Lingula flags can easily be traced from Ogof-ddu on the coast northward to Gwern-y-ddwryd and from thence to Penmorfa and Wern. North of Ogof-ddu the Tremadoc slates must be about 900 feet in thickness as shown in Fig. 23, in which a sketch section is given from the Lingula flags of Ynys-cynhaiarn to the Arenig slate of Pen-ystum-llyn.

Fig. 23.

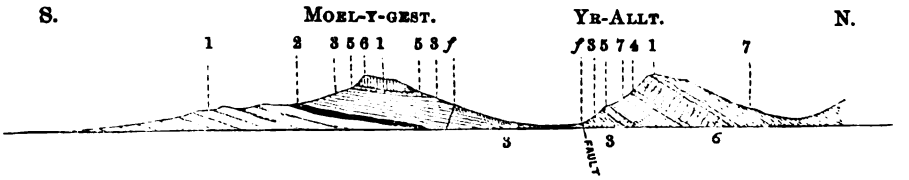


1. Lingula flags.
2. Black and dark blue slate of the Upper Lingula flags.
3. Tremadoc slate.
4. Grit at the base of the Arenig slate, No. 5.

The massively bedded Lingula flags, No. 1, dip west, north, and easterly from a centre on which the ancient church of Ynys-cynhaiarn stands in the middle of the marsh. *Lingulella Davisii* is common in the slates west of Penmorfa and elsewhere in the district together with *Hymenocaris vermicauda*.

The same kind of Lingula and Tremadoc strata surround the greenstone of Moel-y-gest, where a section from south to north shows the following arrangement.

Fig. 24.



1. Thick-bedded banded Lingula flags.
2. Black slaty upper Lingula flags.
3. Tremadoc slates.
4. Pisolitic ironstone.
5. Arenig slates, grit, and pisolitic iron ore.
6. Greenstone of Moel-y-gest and Yr-Allt.
7. Llandeilo and Bala beds.
f. Faults.

CHAPTER XIII.

THE IGNEOUS ROCKS OF CAREG-DU, CWM ORTHIN, AND MOELWYN, AND THE STRATA BENEATH THEM.—THE LINGULA FLAGS, TREMADOC SLATES, AND ARENIG BEDS, AND THE LLANDEILO AND BALA BEDS ABOVE THEM.—THE GREENSTONES NEAR TREMADOC.

The observations on the ground near Tremadoc are partly from personal observation, partly from details communicated by the late Mr. Salter and by Mr. David Homfray, who in this and other districts gave me much valuable personal assistance on the ground in 1874 and 1875, especially in connexion with all the strata from the base of the Menevian beds to the Arenig slates inclusive. The following passages between inverted commas are by Mr. Salter.

"The lowest beds of the Lingula flags to be seen on the road to "Criccieth are at Ynys Cynhaiarn, where the strata arch over, dipping north-"east and north-west; but by proceeding south to Treflys and the coast,* "the Lower black slates are seen, and Morfa Bychan, one mile south of "Trefflys, is occupied by a ferruginous part of the Lingula beds equivalent to "those that lie south of Maentwrog and Ffestiniog; they contain *Lingulella* "*Davisii*, *Agnostus*, and *Olenus;* and they are succeeded by hard standstones "and grits, with fine grained and flaky grey slate, containing crustacea, "*Lingulella Davisii*, in profusion, and, at one locality, tracks of *Cruziana* on "their sandy widely rippled surfaces, *see* Pl. 3. These sandy beds are often "micaceous and grey coloured, striped with whiter bands, very few of the "upper beds being coarse grained. *Lingulella* is also found at Bron-y-foel; "*Hymenocaris vermicauda* and *Lingulella* at Careg-felen, at the entrance of "the lane to Y-Wern; also at Bryn-twr summer house; and especially on the "hill descending to Penmorfa Church, the shells are most abundant. Borth, "a mile south of Port Madoc, is a good locality for all these fossils.

"The grey micaceous slate is very little affected by cleavage in this middle "part of the series, the layers thin and wavy, and in part full of patches of "drifted sand with broken and entire shells. The marks of Annelides cross "obliquely, sometimes under, sometimes above, the surface, and are either in "relief or intaglio. When the latter, they have sometimes a raised edge, as if "pushed up on either side. The solid tubes appear to have been the contents "of the intestinal canal, for the sand is of different texture, and generally "coarser than the surrounding matrix. Details of the mode of occurrence of "these tracks, which have been observed in situ, are given in the Appendix, "where, too, the localities explored by myself and our own collectors, or by "our friends Messrs. Ash and Homfray, are enumerated (*see* pp, 345, 346).

"The higher part of these beds is a smooth grey slate, and on the rising "ground north-west of Penmorfa Church, it is literally crowded with *Lingu-*"*lella Davisii*. It is the equivalent of the beds previously described imme-"diately behind Bryn-mawr and above Tan-y-bwlch, and other places along "the Ffestiniog valley. The whole represents closely, both in lithological "character and organic contents, the beds near Dolgelli.

"Near Penmorfa Church there are thin bedded, fine grained, bluish glim-"mering slates, with ferruginous partings and imperfect cleavage, forming a "low part of the Tremadoc slate. They are underlaid by black ferruginous "slates of the uppermost part of the Lingula series, which, however, are here "by a fault less exposed than the same beds near Maentwrog. Here and

* A fine section of these Lower black slates is visible at the caves of Y-Graig-ddu, between Treflys and Criccieth. The beds are much contorted, overlaid by the whole mass of the Lingula sandstones, which are succeeded towards Criccieth by the Tremadoc slates and Arenig and Bala beds in regular succession.—J.W.S.

" there striped layers show alternations in the sediment, and just under the " church, contain *Conocoryphe invita, Olenus alatus* (Pl. 4), *Agnostus princeps,* " and *Lingulella lepis,* besides numerous impressions of *Orthis vaticina,* ob- " served in these strata for the first time. On the east side of the S.S.E. fault " at Bron-y-foel slate quarries, and near Y Wern they are lost, the Lingula " flags without the intervention of the black slate being succeeded by the " Tremadoc slate, on which the true, lower, sandy Lingula flags abut on the " west of the fault that runs S.S.E. from Y Wern. But along the south side " of Moel-y-gest and through the woods of Borth, the succession is clear and " regular, the lower flaggy banded beds being succeeded first by the black " upper Lingula flags, with its characteristic trilobites, and then by the Tre- " madoc slate."

On the north side of Moel-y-gest there is a fault striking E.S.E., as shown in Fig. 24. It is a downthrow on the south. The underlying strata have been altered by the direct action of heat, due to the overlying greenstone, which, with the underlying strata, dips northerly from 14° to 45°.

" On the north side of this fault there are beds of grey, sandy, thin-bedded, iron-stained Lower Tremadoc slate, sometimes striped." Where unfaulted they rest upon the upper Lingula flags, and on the other side of the marsh are of considerable thickness, as seen in the lane that leads north-east from Penmorfa Church to the Caernarvon road, where they dip a little north of east. They are also well shown on the new road from Penamser to Port Madoc, and are everywhere easily distinguishable by their thin bedded character, and their containing more iron than the black slaty beds of the upper Lingula flags N.N.W. of Penmorfa Church. They are soft in texture, and the iron stains occur both in the lines of bedding and in those of imperfect cleavage. This fault, according to Mr. Salter, is one of many small faults which complicate this district, and it does not seem to affect the beds west of Penmorfa.

" South of the tramway which runs from Tremadoc to Brynkir, the Lingula flags and overlying black slate are seen to be followed by precisely the same succession of beds as that given for the Penrhyn promontory, p. 86, viz., iron-stained dark earthy Tremadoc slates, followed by harder and greyer beds with felspathic lines (often a ribbon slate), followed by softer slaty Arenig beds that, much obscured by shingle fallen from the cliff, underlie that hard porcelanized slate upon which the greenstone of Yr-Allt rests. The series south of Moel-y-gest is even more clear, the hard bluish grey beds being still more indurated by the intrusion of the greenstone, which is on a lower stratigraphical horizon than that above Tremadoc (Fig. 24). At Borthwood the best section of all is seen, and the black slate full of trilobites is followed at once by the iron-stained thin Tremadoc beds, which, indeed, occupy the whole area from Borth harbour to the south flank of Moel-y-gest. Their lowest layers contain only *Dictyonema sociale,* but a hundred feet higher they are rich in trilobites, *Psilocephalus* and *Niobe* (*see* Appendix), together with Theca and the small *Lingulella lepis.* The numerous S.S.E. faults render it difficult to trace any set of beds continuously. The entire section, however, along the cliff to Port Madoc shows a fine series of the pencil slates (Upper Tremadoc), and the large quarries are opened in their upper portion. A thin lenticular line of trap along the crest of the hill from Morfa Lodge conducts us to the fossil locality of Tu-hwnt-yr-bwlch, whence Messrs. Homfray and Ash obtained nearly all the Upper Tremadoc fossils. As these are known in the corresponding beds of Garth on the opposite shore of Tracth-mawr, *Ogygia, Cheirurus, Asaphus, Conularia, Orthoceras,* &c., &c., there can be no difficulty in identifying the two sections. The same beds are less perfectly seen ranging along the Tremadoc escarpment under the greenstone and above the iron-works. These very thin-bedded flags occupy all the hill about Tyddyn-dicwm, west of Penmorfa. They are somewhat ferruginous, obscurely cleaved, and contain *Asaphus affinis.* At the top are soft blackish layers; and these are succeeded by very thin bedded, light, grey, and black slate. The same beds occur on the road from Penmorfa to Tremadoc, and above Tremadoc itself, and, both from position and fossils, are evidently nearly on the same line as the soft beds of slate at Plas-newydd and Minffordd on the opposite shore."

Arenig Beds.—Above these is a bed of slaty pisolitic iron, near the top of the hill that overlooks Tyddyn-dicwm north of Penmorfa Church, and this is succeeded by fine-grained pale altered slaty beds. These beds lie studded

with cubes of iron pyrites all along the hill under and in places also above the greenstone of Yr-Allt, by which the rock is partially altered. The greenstones form a very remarkable feature in the landscape, and in a noble range of cliffs run all the way from Tremadoc to the neighbourhood of Brynker. Being more or less intruded between the slaty strata they are in a manner interbedded, and in a sense may be considered as the general equivalents of the greenstone of Garth overlooking Traeth Mawr, even though at the latter place the greenstone underlies the grit that forms the base of the Arenig beds, while in the Tremadoc region they have been injected in and among the Arenig slates. The altered slaty beds in contact with them contain many *Annelide trails*. A probable N.N.W. fault runs between Penmorfa and Yr-Allt-wen.

"Above Tremadoc the altered slates pass through concretionary bluish "slates into the dark grey or black slate of Cwm-mawr, on which rests "black slate, with felspar crystals, which passes into a flaky felspathic ash "bed, that runs for nearly 2 miles north-west from the marsh at Tan-yr-allt." This is the equivalent of the bed of ash that forms the hill south of Hir-ynys, on the opposite side of Traeth Mawr, and the strata are, therefore, the equivalents of the beds of Llyn Trwst-y-llon and the south slope of Moelwyn-bach. "On the Tremadoc side of the estuary the ash merges above into ashy slate, "with concretionary grains, which is succeeded by the highly crystalline "greenstone of Bwlch-y-moch, which alters the rocks both above and below. "Those above consist of hard felspathic, fine-grained, spotted flags, with "*Annelide trails*," well seen at Porth-treuddyn.

Though apparently these greenstones often for a long space adhere rigidly to the line of strike, they are certainly intrusive, for the rocks have been equally hardened by heat, both below and above, a circumstance that gives them a value as flagstones, for which purpose they have been extensively quarried between Bwlch-y-moch and Porth-treuddyn, and also near Yr-Allt. The flags are mostly of a light grey colour, and look as if partly composed of felspathic matter, a circumstance that may have aided in their alteration during the intrusion of the melted greenstone. Mr. Selwyn remarked, that in some places they looked as if crystallization had commenced.

Above this are blue slates equivalent to those of Moelwyn, Cwm Orthin, the Ffestiniog slate quarries, and that part of the Arenig or lower Llandeilo beds generally that immediately overlies all the felspathic porphyries and ashes that range from thence to Arenig and the Arans. Considerably higher in the series there are the sandy slates and grits of Mynydd-y-gorllwyn, well charged with the ordinary Bala fossils, both here and also north-east of Ynys-wen near the neighbouring lake of Ystrallyn.

The Moelwyn Range, &c.—North of Ffestiniog the felstones and ashes of the neighbourhood attain their greatest development on the two Manods, where the porphyry beneath the ashy and slaty beds north of Llyn-y-Manod is of remarkable thickness. Westward of these mountains, on the rugged hills that overhang the entrance to Cwm Orthin, and on the eastern cliffs of the two Moelwyns, the interbedded porphyries, ashes, and volcanic conglomerates strike to the south-west, but beyond Moelwyn-bach they become rapidly thinner, and finally die out altogether in the country on either side of Traeth-mawr. The whole of the volcanic series is more or less interbedded with dark blue slates of the age of the Arenig beds.

The rocks of the Moelwyns being identical in general position with those of the Manods, Lyn Conwy, and the Arenigs, it follows that the strata between Moelwyn and the grit at the base of the Arenig slates described in last chapter, are the equivalents of the fossiliferous Arenig beds of Tai-hirion and the Manods, and proceeding westward along the line of strike across Traeth-mawr to the hills north of Tremadoc, we find the same set of strata, both

below and between the lines of greenstone that form Yr-Allt and the cliff north of Bwlch-y-moch.

Faults.—The vertical throw of the north and south fault that skirts Manod-bach is probably not less than about 2,000 feet, for the rocks dip north at angles of from 15° to 20°, and the whole country is thrown down and forward on the east, so that the lower margin of the Manod porphyry is separated more than a mile from the mass immediately east of Careg-du, which is its equivalent on the west side of the dislocation. The Ffestiniog and Trawsfynydd fault, which passes north into the region of the slate quarries, is also a downthrow on the east of about equal amount in this neighbourhood, and several minor cracks lie between them, the principal of which affects the felstone porphyry throwing Careg-du down on the west. Looked at from Ffestiniog, Careg-du seems like a mass of rock lying in a broken synclinal curve. This general arrangement of the strata is due not to the masses having been thrown by successive steps *forward* to the south, but is the combined result of downthrow and denudation.

The Careg-du* porphyry corresponds to that of the Manods. It is of the ordinary felspathic kind, and in places columnar. A thin band of slate partly altered, underlies it, visible above the road near the southern margin of the felstone. Altered speckled beds underlie this slate, and both correspond to the strata that crop from beneath Manod-bach and Manod-mawr. These slaty bands are interstratified with the Careg-du lavas and ashes, and north of Careg-du two very thin felspathic ashy bands occur in the slates, the whole corresponding to the rocks of the slate quarries already noticed between Moel-bywydd and Llyn-du-bach, and also to those east and south-east of Llyn-du-bach that lie between the faults on the northern half of Manod-mawr.† On the west the porphyry of Careg-du partly *abuts against* those talcose and speckled beds that *underlie* it on the south. This is the result of a downthrow on the east along the Trawsfynydd and Ffestiniog fault. There can be no doubt, then, that the felstone rocks, a little south-west of Tal-y-waunedd (on the west side of the fault near its northern end) are the equivalents of the masses of Careg-du and the Manods, continued south-westerly as far as the broken slopes of Moelwyn-bach.

North-east of the stream that flows from Llyn Orthin above the brook and railway, the lowest of the igneous rocks consists of a thick mass of felspathic ashes and conglomerate. Near the Ffestiniog and Trawsfynydd fault it is hidden by the rubbish of the slate quarries, and on the west, before reaching the stream that flows from Llyn Orthin, it thins out. The agglomerated fragments are both rounded and angular, more generally the latter, and it then becomes a sort of scoriaceous felspathic breccia. It is succeeded by a thin band of slate, which separates it from the felspathic slaggy-looking porphyry that lies between the conglomerate and the slate quarries. This porphyry abuts against the

* About 3 miles north of Ffestiniog.

† See p. 77.

with cubes of iron pyrites all along the hill under and in places also above the greenstone of Yr-Allt, by which the rock is partially altered. The greenstones form a very remarkable feature in the landscape, and in a noble range of cliffs run all the way from Tremadoc to the neighbourhood of Brynker. Being more or less intruded between the slaty strata they are in a manner interbedded, and in a sense may be considered as the general equivalents of the greenstone of Garth overlooking Traeth Mawr, even though at the latter place the greenstone underlies the grit that forms the base of the Arenig beds, while in the Tremadoc region they have been injected in and among the Arenig slates. The altered slaty beds in contact with them contain many *Annelide trails*. A probable N.N.W. fault runs between Penmorfa and Yr-Allt-wen.

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* About 3 miles north of Ffestiniog.

† See p. 77.

fault, near Tal-y-waunydd, nearly four miles north of Ffestiniog, and from thence, passing about half a mile to the south-west, it is interrupted by a short dislocation, beyond which, after a natural break in continuity of about 100 yards, it re-appears, and striking westward, crosses the valley of Cwm Orthin a little below the lake, and rests directly on speckled flags of the Arenig beds. The band of slate, however, that elsewhere separates it from the underlying rocks, very soon re-appears, and both pass south-westerly, crossing the stream that flows from Llyn Trwst-y-llon, immediately below the lake, and finally the porphyry ends about half a mile farther south. Its average thickness is from 300 to 400 feet. Its position on the east of Llyn Trwst-y-llon, and that of the underlying thin band of slate, are shown in the section, Pl. 28, No. 3.* The slate that rests on it is unaltered, while that underneath is often porcelanized and this, in addition to structure, helps to indicate its origin; viz. that it was poured in a melted state upon the muddy sea-bottom, and had cooled before the deposition of the unaltered layers that rest on it. I have identified it with the porphyry of the Manods, for its position with reference to Careg-du on the opposite side of the fault proves this. They underlie the same bands of slate which, interstratified with thin ashy bands, may be traced from Llyn Trwst-y-llon to the Manods and Bwlch-Careg-y-fran.

The line of felstone just described is overlaid by another set of volcanic ashes and conglomerates, which pass from the outflow of Cwm Orthin, through Llyn Trwst-y-llon, and end a little south of the lake.† Like the lower mass it is sometimes brecciated, the included fragments being mostly felspathic, and of all sizes, from a mere grain to nearly a foot in diameter. Rarely it contains rounded pebbles of quartz. A band of slate under Moel-y-rhudd rests on this conglomerate. It has been quarried for roofing slate, but never can be worked with much success, owing to its thinness, and the high angle at which it dips under the immense overhanging mass of the porphyry of Moel-y-rhudd and Moel-wyn-bach. Towards Llyn Trwst-y-llon a bed of porphyritic felspathic ashes of about 150 feet in thickness wedges into this slate. It lies on the left of the lake. By means of a series of faults it appears on both sides of Moelwyn-bach, the whole summit of which is much dislocated, the fractures being filled with large veins of quartz. It ends about Hafod-uchaf, near the old road to Beddgelert, and all along its course it is distinctly interbedded, and contains crystals of felspar embedded in a compact blue felspathic base. Above it are beds of slate about 150 feet thick, and these are succeeded by a felspathic lava bed about 900 feet in thickness, that runs from Cwm Orthin along the slope between Llyn Trwst-y-llon and the summit of Moelwyn. Like the other

* Also 6-inch Sections, sheet 28, line 3.

† Marked "felspathic ash conglomerate and breccia," in the 6-inch Section, sheet 28, line 3. The other band of volcanic conglomerate, that beyond Cwm Orthin, underlies the thin band of slate beneath the "slaggy grey porphyritic-felspar trap," does not occur in the line of the section.

‡ Map 75 S.E., Six-inch Section, sheet 28, line 3.

true felspathic lavas of this range it is more or less porphyritic, and often rudely, and sometimes perfectly, columnar.

On the summit of Moelwyn, resting on the felspathic trap, are blue Arenig slates* (Pl. 28, Fig. 3), equivalent to those in the quarries of Cwm Orthin and other great quarries further east. Thin inconstant felspathic and talcose bands containing crystals of iron pyrites occur in these, some of which pass through the quarries on the west of the Ffestiniog fault, and re-appear on its opposite side between Cribiau and the porphyry of Careg-du. These and some other thin layers on Moel-y-rhudd are now in a direct distance of 12 miles the sole representatives of the 800 feet of ashes that lie on the east slope of Arenig, and spread northward from thence to Llyn Conwy.

CHAPTER XIV.

Recapitulation and Summary. — Cambrian, Menevian, Lingula, Tremadoc, Arenig, and Llandeilo Rocks, &c.—Slate.

I have now described in detail the structure, distribution, and succession of the rocks of a large part of Merionethshire and a small part of Caernarvonshire, beginning with the Cambrian grits, and passing across the intermediate strata into a low part of the Bala beds. Before proceeding further I shall sum up the results.

First, then, Menevian and Lingula beds, Tremadoc slates, Arenig slates or Lower Llandeilo beds and their contemporaneous igneous rocks, enclose the Cambrian rocks on the south, east, and north in a crescent-shaped curve, the greatest diameter of which from south to north is about 22 miles. Their average dip is outward from the Cambrian centre. The geological structure of the principal component parts of the stratified (or ashy) and interbedded porphyritic lavas of the igneous rocks that lie among the Arenig slates is simple. On first entering the country, however, one might be apt to suppose that it is formed of greenstones and felspathic rocks, slates, and grits mingled in inextricable confusion, and that its igneous components at least treble in amount what they are in reality; but after all the faults have been disentangled, and ashes and lava-currents, as far as the scale will allow, have been carefully mapped, they resolve themselves (eliminating the intrusive greenstones) on the south and south-east into beds of felspathic ashes and conglomerates mingled with strata of Arenig slate, and to a great extent overlaid by, but partly interstratified with great beds of felspathic porphyry.*

* Many years ago when the survey was begun it was considered impossible to separate all the varieties of igneous rocks, and the maps of this area were published with all the igneous rocks of one colour. Subsequently, however, my experience in the Snowdon district proved the practicability and value of separating all the varieties, and additional lines were accordingly run in Merionethshire by Mr. Selwyn, Mr. Aveline, and myself, and added to the maps.

Where tilted at a high angle, as in the Aran range, these together are about a mile in breadth, but in other places they cover broad tracts of country, where, partly by undulations and partly repeated by faults, they spread over spaces of 4 or 5 miles in width. Except where broken by faults, the felspathic porphyries are continuous from Cader Idris to Llyn Serw, 5 miles east of Ffestiniog, when it disappears for a time, but again comes on in the Manods and Careg-du, and from thence strikes westward to Llyn Trwst-y-llon under Moelwyn. The lower beds of ashes also except where faulted, are continuous from near Llanegryn, 6 miles south of Barmouth, to Moel-llyfn-nant, 6 miles west of Bala Lake, where they cease for a space apparently by thinning out. Thin ashy streaks also here and there are mixed with the slate north of Moel-llyfn-nant. The great mass of felstone that overlies this ash begins near Mynydd-y-fronfraith east of Cader Idris, to be overlaid by a second set of beds of felspathic ashes and conglomerates, which, passing northward along the Arans, attain in places a thickness of from four hundred to almost a thousand feet being about 800 feet thick in the Arenigs. They are continuous as far as the river Machno north of Llyn Conwy, but thin away in the region of the Ffestiniog slate quarries. Arenig, Llandeilo, and Bala beds everywhere overlie these rocks, and, as I have explained, rocks holding Arenig fossils also underlie them near Tremadoc, Garth, under the Manods, at Tai-hirion, and in fact with a few interruptions by faults, all along the base of the interbedded volcanic series of the Arenigs, Arans, and Cader Idris south to the alluvial plain of Peniarth and Aber Dysynni where the series is cut off by the fault that runs down the long straight valley of Afon-felindre. Thus it is that *the whole of the lower interbedded igneous series is included in the Arenig beds* of Professor Sedgwick, called Lower Llandeilo by Sir R. Murchison, and mentioned by Mr. Salter under that name as late as 1866.*

There is another point well worthy of remark, which is, that if we follow these contemporaneous volcanic rocks along their strike westward, both from Cader Idris and Moelwyn, we find that they gradually die away and disappear on the south towards Llanegryn, and on the north near Tremadoc.† The lower ashes attain their maximum thickness under Aran Mowddwy, and rapidly thin away on the north and north-west at Moel-ddu and Y-Dduallt. They are gone under Arenig and imperfectly developed under Moelwyn. The felspathic lava or porphyry is also thickest on Cader Idris and Aran Mowddwy, but south-west of Cader Idris, its true contemporaneous nature on Mynydd Pennant is uncertain. The upper ash attains its greatest thickness on the Arans and Arenigs, and thins away entirely on the south near Penmaen, and on the north by Cwm

* The physical relations to the associated slaty beds of all this lower contemporaneous volcanic series had been mapped by Mr. Aveline and myself several years before the publication of the first edition of this book (1866).

† It will afterwards be shown that the igneous rocks of Llwyd-mawr (75 N.W.) are of later date.

Orthin. Following its strike, it is found to be a lenticular mass of about 23 miles in length by 900 feet thick where thickest, and for the felspathic porphyry and lower ash there is good evidence that each was continuous across a diameter of at least 22 miles, and probably much more, for though they do not rise in the outcrop between the Bala and Lingula beds north of Snowdon* (Pl. 28. No. 3), yet they must continue underground for some distance in that direction. It is hopeless to guess how far the individual beds extend beneath the encircling Bala slate on the east and south-east, although we know that igneous rocks on the same general parallel crop out in the Berwyns and at St. David's.

If on the data obtained by means of the sections that cross this country we tabulate the thickness of the greater masses of volcanic rocks, in order of super-position, they are nearly as follows :—

		Feet.
Cader Idris.		
Upper felspathic porphyry	about	1,100
,, volcanic ashes	,,	150
Lower felspathic porphyry	,,	1,500
,, volcanic ashes	,,	200
		3,950
Aran Mowddwy.		
Upper volcanic and conglomerate	about	700
Felspathic porphyry	,,	1,500
Lower volcanic ashes and conglomerate	,,	3,000
		5,200
Moel-ddu, North end of Aran Range.		
Upper volcanic ashes	about	200
Felspathic porphyry	,,	1,050
Lower volcanic ashes	,,	1,100
		2,350
Y-Ddualltt.		
Upper volcanic ashes	about	(absent)
Felspathic porphyry	,,	1,100
Lower volcanic ashes	,,	1,200
		2,300
Arenig.		
Upper volcanic ashes	about	800
Felspathic porphyry	,,	250
Lower volcanic ashes	,,	—
		1,050
Moelwyn.		

The whole of the equivalent series of the Moelwyn range is about 1,500 feet thick.

* Section, Sheet 28, line 2, and Map 78 S.E

It thus appears that, aided by the repetitions consequent on the Bala and Y-Dduallt and Tai-hirion faults, we are in a condition to prove that between Cader Idris and Aran Mowddwy the lower felspathic porphyry (lava) is equal in thickness; between Aran Mowddy and Moel-ddu, it has thinned about 450 feet, and between Moel-ddu and Arenig 800 feet, while the lower and upper ashy beds, which on Cader Idris have an aggregate thickness of about 200 feet in a distance of 5 miles, have on Aran Mowddwy an aggregate thickness of about 3,400 feet. On Moel-ddu the whole volcanic series is thinner than on Aran Mowddwy, being only 2,350 feet thick; at Y-Dduallt further west it is 2,500 feet thick; at Arenig, 2,300 feet thick; and in the Moelwyn range only about 1,500 feet. The greatest mass of material produced by the volcanic eruptions therefore accumulated at the southern and eastern sides of the area under review, while the whole of the volcanic rocks of this epoch (that of the Arenig or Lower Llandeilo slates) thin entirely out west of Dolgelli and Tremadoc. This seems to indicate the probability that, before the denudation of the country had removed the Silurian rocks from above the Cambrian dome, the contemporaneous igneous rocks of the Arenig and Y-Dduallt ranges did not as a whole stretch westward in continuation of their present outcrops, beyond the existing terminations of their north and south horns at Tremadoc and Llanegryn. There is, therefore, not much likelihood that the chief volcanic centres were in the Cambrian region where these rocks are now exposed at the surface, for most of its igneous rocks are mere dykes, and the larger erupted patches, near the centre of the Cambrian anticlinal, are small in size, compared with others that break through the Silurian strata. The volcanic centre, or centres of this series were, therefore, probably to the eastward of a line drawn between the points where the volcanic rocks thin away near Tremadoc on the north and Llanegryn on the south, and some of the felspathic masses that break through the Silurian strata may indicate the position of volcanic centres, or, in other words, portions of the melted matter situated *beneath or in* the necks of volcanoes while in action, as, for instance, the erupted felspathic masses of Tyddyn-rhiw and Gelli-llwyd-fawr south-west of Dolgelli, of Y-Foel-ddu near Aran Mowddwy, and possibly of part of the felspathic masses near Arenig. The great boss of Rhobell-fawr with its ashy agglomerates was also undoubtedly a centre of eruption.

Besides these, and irrespective of the greenstone dykes of the Cambrian region which chiefly run S.E. and N.W., there are numerous erupted masses varying in character, but conventionally massed as greenstones, and it may be asked whether or not some of them may not also have directly underlain centres of eruption. It is certainly the case that some of these greenstone bosses seem to contain more felspar than hornblende, but taken as a whole most of these intrusive masses among the Lingula flags are more hornblendic than any part of the great lava currents, which only in a few instances for a little space might doubtfully be entitled to the

appellation of greenstone, and it is, therefore, more than improbable that a deep-seated mass, which, when cooled, crystallized into greenstone, could have overflowed in lava beds of more purely felspathic quality. The proportion of their ingredients are different, and in no single case in Merionethshire is there any line of greenstone that can be proved to have flowed across a land surface or sea bottom. There may be some difficult cases, and there are many in which a cursory examination would recognise no difference between their mode of occurrence and that of the felspathic lavas, but a thorough acquaintance with the igneous rocks of Merionethshire will show that in no single instance is it safe to include any line of greenstone in the list of lava currents, and most of them may safely be dismissed from that category. Nevertheless, it is not the less certain that they are intimately connected with the volcanic phenomena of the district, for it will be observed in the area under review that all of them lie either *among or beneath* the felspathic porphyries and ashes interstratified with the Arenig slates, or in the case of most of the greater masses, among the Tremadoc and Lingula flags themselves. They are, in fact, never found in the Bala beds of Merionethshire that overlie on the south and east the interbedded igneous rocks, and where they occur in the Bala rocks, between Ffestiniog and Llanberis, it is under circumstances which it will be shown bear the same relation to a later set of volcanic phenomena that the greenstones of the Lingula flags do to the felstones and ashes of Merionethshire. One of those difficulties that occasionally arise with regard to these greenstones is somewhat remarkable, and consists in this, that they sometimes seem to occupy the place of some of the ashes. Thus, for instance, at Craig-y-Benglog* the ashes, as it were, strike directly at the greenstone, which, being intrusive and branching, might be expected to squeeze out and turn aside the strata. This it does not do. However strange it may appear, this circumstance almost induces the belief that some greenstones have been formed by the melting of a part of the ashes amid which they lie. Taking the greenstones as a whole, all I can definitely say about them at present is that the common and obvious explanation of their mode of occurrence would seem to be that during the time of volcanic energy the matter that forms some of them was burrowing hither and thither in the bowels of the volcanic district; while the fact that some of them seem to replace missing portions of the strata would seem to point to the circumstance that they have been formed in place by the fusion of these strata themselves. Under either hypothesis, why the melted matter, often so hornblendic, did not sometimes reach the surface and overflow I cannot explain, except on the untenable hypothesis of some kind of transmutation of mineral matter.

Fossils of Garn and Tai-hirion.—Between Cader Idris and the Machno, north of Llyn Conwy, I am not aware that fossils have

* About 6 miles N.E. of Dolgelli.

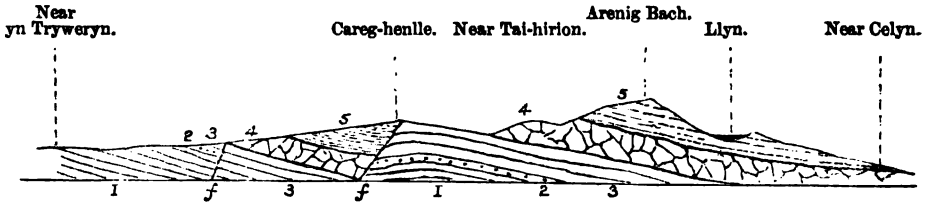
been found in the slates that rest *immediately* on any part of the igneous series. But near Garn, four miles north-west of Bala, I found in the year 1847 certain fossils in coarse black slates faulted against the igneous rock by a downthrow on the south. The fossils are, however, from beds which, omitting the interbedded ashes, would not be far above the horizon marked No. 1 in Fig. 16, p. 67, and consist of the following species, determined by Mr. Salter: *Orthis Actoniæ, O. biforata, O. insularis, Strophomena spiriferoides, Leptæna quinquecostata, Favosites fibrosus, Bellerophon bilobatus?, Ischadites, Ampyx mammillaris,* with species of *Asaphus?, Cybele, Lingula, Ctenodonta, Orthoceras,* &c. (see Appendix). Most of these are Llandeilo species, and all of them range into the Bala beds except the *Ampyx.*

Immediately *underneath* the bedded igneous rocks near Tai-hirion,* Mr. Salter observed in coarse black slates with grains of sand, hard grey and striped sandy slates, and soft, black, earthy slates. The following fossils were found in the slates No. 3, Fig. 24: *Ogygia Selwynii, Calymene parvifrons, Orthis calligramma, Diplograpsus pristis,* with imperfect specimens of *Agnostus, Asaphus, Angelina?,* and *Theca.* To these may be added, since obtained, *Orthis lenticularis* and an *Obolella plicata.* These strata belong to the Arenig slates, and most of the species are characteristic of that horizon, but it is noteworthy that if Mr. Salter's determinations are correct, some of the forms are also characteristic of the Llandeilo and Bala beds, viz., *Diplograptus pristis?* and *Orthis calligramma,* while genera of *Agnostus, Asaphus,* and *Theca* (the species unfortunately not named by Mr. Salter) are well known in the Llandeilo beds.

The following section explains the arrangement of the rocks near Tai-hirion.

Fig. 25.

SECTION FROM ARENIG BACH TO LLYN TRYWERYN.



1. Tremadoc beds.
2. Grit at base of Arenig slate.
3. Arenig slate.
4. Felspathic porphyry.
5. Felspathic ash.
f. Faults.

The slates marked 3′ are the equivalents of the fossiliferous slates No. 3, which are near Tai-hirion, and underneath these beds, about two miles to the north-west at Carnedd Iago, there are beds of grit at the base of the Arenig beds and a thin ashy band immediately underneath the felspar porphyry of Cerig-y-bala. These grits are highly felspathic. On Carnedd Iago above

* About a mile S.W. of Arenig Bach.

the grit in Arenig beds not far below the Arenig porphyry, Mr. Salter found *Asaphus affinis ?* and *Orthis calligramma ?*; and further down we come to the Tremadoc slates and undoubted Lingula flags containing Lingulella Davisii at Llyn-y-Dywarchen.*

We have, therefore, in this neighbourhood evidence of the succession of life on several horizons. First, the ordinary Lingula flags, above which are Tremadoc strata containing *Agnostus, Ogygia,* and *Asaphus.* Above the latter, Arenig slates occur with *Graptolites, Theca,* and *Orthis calligramma ?,* and not far above this volcanic series fossils are found which range upwards into the heart of the Bala beds or Caradoc sandstone. The whole of the Lingula and Tremadoc strata here and elsewhere in North Wales were deposited before the commencement of those volcanic outbursts that over the sea bottom of this area spread many hundreds of feet of volcanic ashes and streams of molten lava.† These outbursts began during the deposition of the Arenig slates which, according to the late Mr. Salter, have less palæontological connexion with the Tremadoc slates beneath than the Tremadoc slates have with the Lingula flags or the Lingula flags with the Menevian strata. This, in my opinion, is the accompaniment of a stratigraphical break between the Tremadoc and Arenig beds, as argued at pp. 204, 210, 214, and Chap. 27, while between the other formations named above there is a general conformity of stratification. The fossils in the third horizon above the igneous series are genera and species common both to the Llandeilo and Caradoc or Bala beds, and in all the strata above the Lingula flags the Brachiopoda of this district are common to the Lower Silurian rocks generally. The disturbances, therefore, that accompanied the igneous outbursts had no essential connexion with any change of the life of the time.

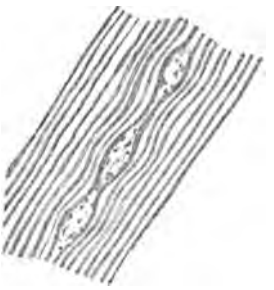
Slate.—With a few remarks on the slate of this part of the Silurian beds I shall conclude. In the Ffestiniog slate quarries when the geological survey was first made, interrupted bands of grey greenstone were seen to pierce the slates in a remarkable manner, sometimes seeming to lie between the beds, sometimes between the planes of cleavage, and sometimes coinciding with neither. In the great quarry west of the Ffestiniog and Trawsfynydd fault the cleavage dips from 45° to 50° north-west, the inclination of the beds being about 35° in the same direction, and a greenstone dyke ran through them between the cleavage planes in the manner shown in the following diagram, bulging and thinning off in a rapid succession of oval-shaped masses of 3 or 4 feet in length. Associated with it are quartz veins occurring principally at the points between the separate bulgings of the greenstone. In another case in the same quarries a large grey kidney-shaped mass was exposed. It was somewhat amygdaloidal,

* Four miles east of Ffestiniog.

† The same assemblage of fossils is found in beds that lie low in the Arenig beds west of the Stiper Stones, and these horizons are both lower than any of the strata that rise in the dome of the Berwyns, or in the Llandeilo flags of Caermarthenshire. In Pembrokeshire they occur.

and its vesicles were filled with quartz or with carbonate of lime coated with quartz. It was certainly one of the edges of a dyke

Fig. 26.

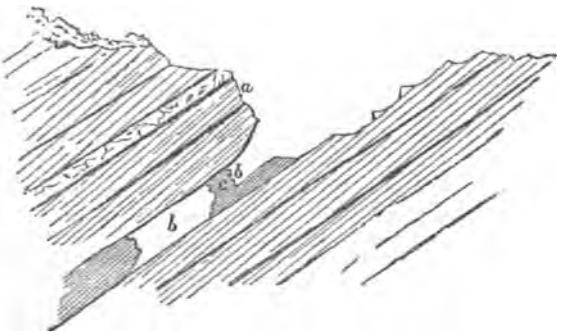


that never saw the light till laid bare by denudation and the operations of the quarrymen.

It is not to be supposed that the greenstones are in this region all precisely of one date, but for many reasons it may be considered certain that the majority of those *that lie more or less between the beds* were injected in Lower Silurian times, in which case they were of prior date to the greater disturbances of the rocks, and consequently to the development of the cleavage of the country. This, however, is not invariable, for it will be shown that in Caernarvonshire, in the Penrhyn slate quarries, some of the common *vertical* dykes include fragments of cleaved slate. These which run north-westerly I believe were injected at a much later date. In the case of the greenstones described (diagram 26), it appears that being injected nearly in the lines of bedding, and the forces that caused the cleavage having produced it nearly in the same plane, the igneous rock has interfered with the regularity of the cleavage, which near the greenstone assumes a wavy instead of a rectilinear character.

It is to modifications on a large scale, induced by change of lithological character, cleavage, joints, dip, and position of the strata, that the availability of the same set of beds for slate making depends in different localities. Thus in one of the Ffestiniog quarries the rocks lay nearly thus, and were described by me in 1866 as follows:—

Fig. 27.



A large quantity of slate has first been quarried from the surface, but as the strata dip north about 35°, and as the hills also rise behind the quarries in that direction, the top *a*, which consists of weathered and valueless slate, is so thick that it will no longer afford the expense of removal, and consequently the quarriers have for long followed the profitable bed *b* on its dip by an excavation, which, as the work proceeded, increased in length and depth. The roof is supported by pillars *c* of slate left for the purpose, and the day may come when, following the dip, the workmen will reach a depth too great for the profitable continuance of the work. The pillars form a fertile source of anxiety, for they have sometimes given way and slipped in the direction of the dip, large masses of ruin falling in on the workings. The foregoing instance makes it evident that much depends on the size and form of the "top," and if the beds dip and the surface of the country slope in the same direction, they lie advantageously for working, for the quantity of "top" *a* may not be so much increased but that it may be entirely removed. Many other cases may be cited, but these form two of the more typical instances of the manner in which the same beds are affected by the form of the ground in the locality of the Ffestiniog slate quarries, without reference to other conditions, such as the presence of multiplicity of joints, imperfections in the cleavage, or other changes in the structure of the rock. Some of the quarries of the district further east are worked open to day. There can be no doubt that the strata by Llyn-bywdd are of the same geological age with those of the large quarries between that pool and the Manod-bach fault, and also with those of the great quarries west of the fault that bounds the porphyry of Careg-du; but the beds of slate east, west, and south of the lake are thinner than at the quarries, and the interstratified ashes and conglomerates have greatly increased in thickness. North of the lake the beds should be the equivalents of the upper strata of the great slate quarries. The slate of the quarries on, and of those a little east of Manod-mawr, are certainly the equivalents of the lower part of the quarries a little east of the Manod-bach fault, for they are interstratified with the same ashy beds which have grown thicker. The Rhiw-bach slate, which dips north at an angle of about 18°, is probably a little higher in the series, but this is uncertain, the adjoining ground being obscured by drift.

Slates have been quarried to a small extent further south, in beds which are the general equivalents of those mentioned above. They lie at and near Llyn-y-drumboeth, where, as already explained, they are interstratified with trap sand ashes, the whole dipping north and north-east at comparatively low angles, so that in working them it would sometimes be necessary to remove a "top" of hard rock so heavy and thick, that like the strata under Moel-y-rhudd it might not repay the labour. These details are, however, almost foreign to the general description which is the main object of this Memoir, since each individual case would require a special survey to illustrate all its capabilities.

Since I first surveyed the country quarries have been opened on Moelwyn in beds which are the general equivalents of the old quarries of Cwm Orthin, and openings have also been made in Cwm Croesor in strata which I believe must be somewhat higher in the series.

In the slate that overlies the Gamallt porphyry, the lower strata are the equivalents of the slates that overlie the igneous series of Moelwyn, Cwm Orthin, and of those north of Careg-du and the Manods, but whether it be that the material has changed, or that difference of strike has altered those peculiarities of cleavage and jointing that favourably affect the Ffestiniog slate, certain it is that no quarries of any importance have been opened between the Gamalt trap and the fault on the east that runs from Caregog to Ffynnon Eiddew. My own opinion is that change of strike affected the lateral pressure which during the contortion of the strata of the country produced a slaty cleavage which, in all these parts of Merionethshire, is less perfect with a north and south than with a N.E. and S.W. strike. The same holds true of all the equivalent strata that rest on the ash from the Machno fault, near Pen-y-fedw,* to Mynydd Nodol and Arenig. Indeed, all along the Arenig and Y-Graig range the superincumbent beds are a kind of soft black shale rather than slate; and though here and there openings have been made in the corresponding rocks immediately east of the Arans, and from thence along the strike to Mynydd Ceiswyn,† no important slate quarries have been worked in those areas, and the same holds true all along the strike of the slaty strata that *directly* lie on the igneous series of the Arenigs, Arans, and Cader Idris far south to the Alluvial flat of Afon Dysynni north of Peniarth.

* One mile and a half S.S.W. of Penmachno.
† Three miles and a half south-east of Dolgelli.

CHAPTER XV.

The Caradoc or Bala Beds South of Cader Idris, and between Dinas Mowddwy and Bala Lake.

General Description.—With the formation of the highest porphyries and ashes of Merionethshire there closed a time of volcanic activity in the area described in previous chapters. This was apparently succeeded by a long period of repose, during which a thick series of slaty beds were deposited above the porphyries of Cader Idris, the Arans, the Arenigs, and of the two Moelwyns. But long before the close of the deposition of the Bala beds, and long after the volcanic rocks of the Arenig series had been buried deep under later sediments, the volcanic energy was renewed in part of the same general area. I shall now describe this part of the series lying in the country between Dinas Mowddwy, Caernarvon Bay, and Conway, beginning my description with the ground near Dinas Mowddwy, and following the Bala beds, by Bala, Llangwm, and Yspytty Evan, to Penmachmo, From thence, I shall resume the account of the mountains north of Moelwyn, and afterwards explain the structure of the large tract of Silurian and Cambrian country that lies between Penmachno, Tremadoc, and the Menai Straits.

Bala Beds, Cader Idris, Aberdovey, &c.—Between Cader Idris and the river Dyfi the country has been described by Mr. Selwyn, as consisting of "dark blue and grey arenaceous and argillaceous "slates, with thin beds of very fine grained grey and brown "banded sandstones." Both are occasionally flaggy, especially between the Dyfi and the high range of hills that strikes north-east from Pen-y-graien to Garnedd-wen. This range is chiefly occupied by blue slate interstratified with thin grits, and occasional thicker beds of quartzose sandstone and conglomerate, partly composed of felspathic grains. These, with several large and small anticlinal and synclinal curves, in the main dip south-east at high angles, and bands of good roofing slates, and flags occur on their south-east flanks, largely quarried at Corys. The whole country being contorted, it is likely that the sandy beds that form the hills above Pant-y-carneddau and on Mynydd-llyn near the road from Machynlleth to Towyn, may be the representatives of the above-mentioned sandstones. In spite of cleavage, a contortion still more intense is evident in the rocks exposed along the shore between Machynlleth and Towyn, where they principally consist of grey and light blue arenaceous and slaty beds, similar in structure to many of the rocks that lie between the Dyfi and Plymlumon. Their strike is south-westerly, and the cleavage more or less coincides with it, generally dipping south-easterly from 80° to 85°, though it is occasionally vertical. The great Bala fault runs through this district from Llyn-trigraienyn, by Tal-y-llyn, down the long straight valley to Morfa-Towyn. Its amount is unknown, but, judging by the strike of the rocks, it probably decreases near Tal-y-llyn, and again increases towards

Towyn, for the S.S.W. strike of the strata between the estuary of the Mawddach and Afon Dysynni, under the alluvium of Morfa Towyn, must bring the Arenig, Tremadoc, and Lingula beds against the Bala beds, which between Peniarth and Towyn strike W.S.W.

Between Aberdovey and Towyn fossils are said to have been found, but they are certainly scarce, for, in spite of diligent search, none have been discovered anywhere else between Aberdovey and the Bala limestone beyond Dinas Mowddwy, although, judging by strike, position, and occasional slightly calcareous appearances, it is not unlikely that some of the rocks of the sandy beds of Pen-y-graien and Garnedd-wen may be on the general parallel of the Bala limestone, or of the fossiliferous strata not far below.

Wales South of the Dyfi.—Bala beds, with the Lower Llandovery rocks, form the greater part of the Silurian strata of Wales south of the river Dyfi, occupying the west of Montgomeryshire and Radnorshire, the whole of Cardiganshire, and by far the greater part of the county of Caermarthen and a smaller part of Pembrokeshire. A fault runs from the sea up the course of the Dyfi, possibly as far as Cemaes, the strike of the strata on its opposite banks being discordant, for while the beds north of the river trend south-west and north-east, south of the river, at least as far as Machynlleth, their strike is much more northerly. The Bala and Lower Llandovery rocks are spread over this great area of more than 2,000 square miles by innumerable undulations of the same strata, but north of Cemaes the very rocks that, south of Cader Idris, form more than half of the Lower Silurian region of South Wales, are comprised in the narrow strip of hilly ground four miles in width, that lies between the Denbighshire flagstones and the Arans. They are there less contorted, and dip more steadily eastward, and nearly 14,000 feet of strata are squeezed into this narrow breadth* (Fig. 12, and Pl. 28, No. 3).

Dinas Mowddwy.—Near Dinas Mowddwy fossils were found on Moel Benddu, Moel Dinas, Blaen-y-pennant, and further north at Pum-rhyd, in black earthy slates. They consist of ordinary Caradoc species *Trinucleus concentricus, Asaphus Powisii, Berychia complicata,* together with *Orthis vespertilio, O. Actoniæ, Strophomena expansa, Leptæna sericea,* and several corals and shells, much distorted by cleavage.

Bala Limestone.—Immediately to the north of Dinas Mowddwy a set of beds begin to appear near the middle of the dark earthy slates, rather different in general lithological character from the beds to the south-west. These beds have been long known as the Bala beds, and were years ago proved to be the equivalents of the Caradoc sandstone of Shropshire.†

* The area referred to is shown in Map pl. 27, or in the one-inch maps, sheets 40, 41, 42, N.W., 56, 57, 50, 60, and 74; Horizontal section, Sheets No. 26, lines 2, 3, and 4, and 29. Line 3 shows the structure of the contorted country south of Cader Idris, and of the 6 miles alluded to east of the Arans.

† What follows in inverted commas as far as page 112, was contributed by the late Professor Jukes, except in one or two cases expressly mentioned. Mr. Jukes surveyed the chief part of the Bala beds, between Dinas Mowddwy and Penmachno.

"In the middle of the Dyfi, half a mile north-east of Dinas Mowddwy, may be seen a small band of dark limestone, about 3 feet in thickness. This is the first appearance of the Bala limestone."

This limestone runs in the middle of the series, first in a long straight line with a north-east strike as far as Craig-yr-ogof, and afterwards near Bala broken and repeated by faults.

"The Bala beds spread over a broader area and become highly fossiliferous as they go northwards, and in the neighbourhood of Bala Lake assume the following characters:—

"The principal mass of them is a very fine-grained arenaceous slate rock, of a light grey colour. This commonly contains very minute flakes of mica, which, as well as the grains of other minerals, are so small as rarely to be distinguished by the naked eye. Some of the beds are very hard and compact, with a conchoidal fracture, others are affected by a slaty cleavage, but this is commonly irregular, and not well pronounced, and they never afford anything like good roofing slate.

"About the middle of this set of beds occurs the band of limestone. This has a well-marked and peculiar lithological character, which it preserves almost throughout its entire course. Some parts of this limestone differ but little from the sandy slate rock in which it lies, except in being calcareous, but its more well-marked portions contain bands from 1 to 6 inches thick, of a nodular or concretionary character, the centre of the nodules being crystalline grey argillaceous limestone. These nodules so blend one into the other as on the weathered surfaces to form rough projecting bands or mouldings standing out from the face of the rock. The space between each band is commonly about the same width as that of the bands themselves. The lowest part of the limestone frequently contains large nodules or concretionary masses of a black crystalline limestone, which sometimes forms a regular bed, about 3 feet in thickness, with veins of white spar. The thickness of the whole calcareous mass commonly does not exceed 20 feet, and rarely even attains to that magnitude. Besides the fossils of this limestone, which will be named hereafter, it is very frequently characterized by the occurrence of small black nodules, of the size of a walnut, that often remind one of coprolites. Some of these were analysed by Dr. Playfair and found to contain a large proportion of phosphate of lime.

"About 1,200 or 1,400 feet below the limestone are some beds of a peculiar lithological character called "ash" in this Memoir.* These ash beds are of three varieties,—the flaky, the brecciated, and the crystalline. The first is the most characteristic, in which the granular materials of which the rock is more or less composed are coated, and separated by flakes of a smooth fine texture, often resembling chlorite, which on a fresh surface of the rock give a soapy feel when rubbed in one direction. These flakes lie pretty nearly in one plane, but that is very often

* "The ash beds were well known to the people of the country, by whom they are "called 'cerrig llwydion,' 'the grey or brown stone.' A house on the west side of "Bala Lake is thus named from standing on a bed of it."

not parallel to the plane of stratification, but perhaps most commonly oblique, or even at right angles to it. The crystalline varieties differ from the flaky chiefly in the granular portions, which consist in a great measure of distinct shining crystals of felspar or other minerals, with their angles scarcely at all worn, and their facets quite bright. They are with difficulty separable from the matrix. The brecciated ash beds are, as their name denotes, made up of worn but still angular fragments of rock, varying from mere grains to pieces half an inch in diameter, compactly imbedded in a fine-grained matrix of much the same mineral character as the fragments themselves. Many of these fragments are pieces of felspathic trap, the crystals of felspar being easily recognised in them. All these varieties pass into each other or alternate in the same beds, being separated here rather for convenience of description than for any real distinction between them. One remarkable circumstance is, that these ash beds are almost without exception sufficiently calcareous to effervesce on any new surface with very dilute muriatic acid, a quality which is never perceptible in the grits or slate rocks immediately above or below them.

"The external appearance of the ash beds, as seen where they crop out on a hill side, at once distinguishes them from the ordinary sandy slate rock of the rest of the Bala beds. A bed of ash only 2 or 3 feet thick can be traced by its more massive appearance, and by the rounded form and greater distinctness of its blocks. When its thickness reaches to 10 or 15 feet it often forms a feature that can be discerned at the distance of half a mile, and its aspect very frequently resembles that of protuberant trap dyke. The lamination of a thick bed of ash is rarely perceptible, the stratification being determinable only by its upper and lower surfaces. Sometimes, however, it contains bands of a different texture from the rest of the mass, which then coincide with the general planes of bedding, and show its strictly stratified character. From the singularly broken and disturbed state of the country occupied by these beds it is rather difficult to say with perfect accuracy how many ash beds the Bala rocks contain in the immediate vicinity of Bala. In part of the district, at all events, there appear to be certainly two having the same mineral character. In one or two places also an ash bed of a rather different character from the others, and generally more crystalline, appears immediately below the limestone.

"In order to understand the lie of the Bala beds it will be best to describe in detail the range of the Bala limestone from its commencement in the bed of the Dyfi, near the flannel factory of Aber Cowarch, a little north of Dinas Mowddwy. From this spot it runs by Pen-y-bryn, Bryn Sion, Bwlch-y-Sygyn, and at the head of the vallies of Cwm Escyll, and Cwm Dinewid.* It is also seen occasionally peering from under the bogs at the tops of the intermediate hills, and is admirably shown in the valley of Blaen-y-pennant, which it crosses one-third of a mile west of the

* Cwm Dinewid is called Afon Penrhyd in the Ordnance map.

turnpike road, and it may be traced thence at intervals across the moors to the west side of Craig-yr-ogof.

"It does not strictly preserve the whole of its characters throughout this stretch of 10 miles, as it in some places loses the black crystalline masses near its base, and in others (Blaen-y-pennant, for instance) the slate both above and below it, for 10 or 20 feet, becomes slightly calcareous, and in places almost as much so as the limestone itself. It is probable, also, that occasionally the calcareous matter almost entirely disappears, as the limestone is not to be seen at one or two spots, where from the strike of the rocks on each side it ought to appear. On the east side of Craig-yr-ogof, one of the places thus poorly provided with lime is actually seen, the beds having the external appearance of the limestone, and all its banded character, but only effervescing very feebly with acids.*

"A little distance to the west of this spot, coming out just from beneath the limestone, is a well characterised ash bed, the first appearance of that kind of rock as we come up from the southward. All the usual fossils of the formation are found in the neighbourhood of the line of limestone throughout this tract, and also for some slight distance in the rocks below it, but do not appear to extend far into the rocks above.

"So far the strike of the limestone is remarkably regular, running in a nearly straight line N. 30° or 35° E., parallel to the outline of the traps of Aran on the west, and that of the Tarannon shale and Denbighshire sandstone on the east. Its dip is E. 30° or 35° S., almost always at an angle of 40° or 50°.

"Throughout this extension the beds near the limestone pass both upwards and downwards into fine-grained rotten black slates, which on the one side lie below the Tarannon shale and Lower Llandovery beds, and on the other rest upon the porphyritic rocks of the Arans. Both the upper and lower slates are occasionally affected by some lerge flexures which, in this part of their course, have not extended into the strike of the limestone.

"Just north of Craig-yr-ogof is a space of about a mile and a half, in which hardly a fragment of rock can be seen near the strike of the limestone, so entirely is the surface covered by thick black bogs and heather. North of this it again suddenly makes its appearance in two places, one about half a mile east by south from the top of Moel-migynau, the other down in Cwm-llysog.† The first-named piece cannot be traced many yards; the latter, however, runs down the brook with many small undulations to a fence and sheepfold, and then strikes up the hill towards the north of the word "Murddyn" in the map, where it is lost under the peat. It reappears south of Maes-meillion, and can be traced thence continuously up to some large limestone quarries and old kilns on the hill side south of Bryn Bedwog. It is here curiously contorted and twisted about in various directions, forming one or two small arches and domes, but none of the pieces run far, and no limestone can be found in the brook

* *See* Section, Sheets No. 29, line 3, and No. 37, line 4.

† About 3 miles S.E. of the southern end of Bala Lake.

beneath; it is evidently cut off by a fault. About half a mile to the north-east, however, just outside the fences on the north of the hill call Moel-fryn the limestone is again found dipping first south-west, then south-east, and then north-east, and a good deal broken and contorted. It disappears again under a bog, but may be detected in the brooks between Bryn-melin and Yspyddadog, whence it can be traced to the quarries of Y-Gelli-grin. It is here again bent and broken, dipping in one place north by east at 15°, then south at 45°, but having a general inclination about E.S.E. Both at the quarries on the north end of Moel-fryn and at Y-Gelli-grin there is a crystalline, calcareous, and fossiliferous ash bed below the limestone, separated from it by about 30 or 40 feet of other beds, and down the road towards the house of Y-Gelli-grin there is a well-marked fault running a little west of north, and dropping the beds to the east about 30 or 40 feet perpendicularly, so as to bring the limestone to the east of the fault exactly into the line of the ash bed to the west of it. As a bank and fence separate the two pieces, this circumstance would be likely to mislead a hasty observer, both as to the number of the beds and their character. These beds cannot be traced below the house, but on the opposite side of the brook they may be seen running north up the hill of Bryn-cut. On the north side of this hill, however, they are abruptly cut off by a fault, and also contorted, as the ash bed is suddenly deflected and made to strike at right angles to its former course, and abut against the limestone, which just beyond suddenly ends. Both beds are again seen about one-third of a mile to the northward between Y-Garnedd and the brook, but very much broken, striking in much confusion in different directions, and in the last piece of limestone neither strike, dip, nor regular bedding can be discerned. On the opposite side of the road the same confusion is observable in the common Bala beds which lie at all angles and positions, and the beds below the limestone are apparently brought into contact with those above it.

"Returning now to the southward to the neighbourhood of Moel Migynau besides the detached piece of limestone to the east of that hill, there is another to the north of it, near a place called Llechwedd-ddu. There is here a small quarry in which the beds of limestone are bent into the sharpest possible angles, but no regular strike or dip is shown. Similar quarries occur at the same level on the opposite side of the glen near Murddyn Marad, but to the north-westward of these there is a regular line of limestone shown on the hill side about half a mile in length, and lying quite undisturbed and nearly horizontal. This ends very abruptly to the north, being apparently cut off by a fault running nearly east and west, on the opposite side of which the dip is south at 30°, or nearly at right angles to its former direction.

"The limestone is next seen much contorted in the bed of the brook north of Caer Hafotty. To the north of this a very regular oval outlier, forming a small basin-shaped piece, supporting a patch of slate in its centre, lies on the hill side, and

north of that again are two other detached pieces, one about 100 and the other about 50 yards long, both very regular and dipping at a slight angle to the south. Both those pieces are evidently cut off by faults running nearly north and south.

"The occurrence of this line of detached pieces from half a mile to a mile west of the limestone before described is due to the effect of an anticlinal curve, the axis of which runs nearly north and south between the two, tilts the beds over at a sharp angle to the west, and repeats the limestone in that direction. This westerly dip, however, is not continued far, the beds very shortly flattening, and then rising to the west so as to form a synclinal line parallel to the anticlinal. Before, however, this synclinal curve is fully carried out some considerable faults occur, running about north and south, and throwing up the beds on their west side. The extension of the limestone is therefore cut off abruptly in that direction. Moreover, as no large faults can exist without cross fractures or curvatures, the portions of limestone are no doubt separated by these as well as by the convolutions of the beds on which they rest."

Beds below the Bala Limestone.—"I shall now trace the rocks below the beds associated with the limestone. I have said that the Bala beds pass downwards into black slates. As they range northwards these beds become affected more and more by flexures and faults, and spread over a greater extent of country than they occupy between Bwlch-y-groes and Dinas Mowddwy. Owing partly to the quantity of drift matter lying on the hill sides south of Bala Lake, partly to the grass and turf with which the rocks are concealed, and partly to there being no peculiar beds capable of being traced in that district, it is impossible to give any other than this general account of it. There is, indeed, an ash bed just under the limestone of Craig-yr-ogof, and another in the brook behind Tai-yn-y-nant, but neither can be traced for more than a few yards. On the east flank of the hill, however, called Cefn-gwyn, south of Llangower, and in the valley between it and the limestone, the ash begins to make its appearance in greater force, and from this point to the northward, ash beds make a permanent and important feature in the Bala group. There is, I believe, on the east side of Bala Lake only one ash bed; this, at its very commencement north-west of Y-Fedw, is broken through apparently by the same fault that cuts off the limestone before mentioned as running north-west of Murddyn Marad. Other dislocations are also apparent in it, but beyond these, from the bed of the brook a little to the northward, it runs in nearly a straight line to the east of Glyn-mawr and Glyn-bach up to the east end of the wood at the back of Pant-yr-onnen. This line is nearly parallel to that of the detached pieces of limestone before described, but the two gradually approach each other towards the north, till on the brow of the hill looking down on Bala Lake the ends of the ash and the limestone are scarce 50 yards apart. A fault running about north by west occurs between the two, and, by following that line, the extension of the ash bed is discovered

on the east side of it, by the road between the words "Bryn" and "hynod" on the map. Just in the same way, however, as the limestone above it, so is this piece of ash shortly cut off by another north and south fault, also a downthrow on the east, and its extension is found a quarter of a mile to the north in the wood of Tyn-y-twll. Here the ash bed has come within the range of the anticlinal line before spoken of, and is affected by it to some extent, its outcrop running south-east and then north-east, but broken in one or two places by small cross fractures. As the ground hereabouts slopes sharply to the north, the bend in the outcrop of the beds makes but little feature in the map, still there is an indentation in the crop of the ash bed answering to the deep east and south flexure in that of the limestone. From this spot the ash bed runs to the N.N.E., frequently broken by faults, throwing it from 50 yards to a quarter of a mile on one side or other of its course, but being generally parallel to the broken line of the limestone to the eastward. One of these faults at least can be traced through both beds, as, if we join the ends of the ash beds west and north of Cornelau by a straight line and produce it to the south, it passes close under the broken limestone south of Bryn-Bedwog, which we saw before must be cut off by a fault, as none of it is found in the brook below. It would be tedious to enter further into details, neither is the scale of the Ordnance map sufficiently large to show them, or even to make all of them out in the field except in a general way. The reader, indeed, must be advised that the faults marked in the map are rather a selection to show their general nature than a true representation of those which could be shown to exist did the scale of the map allow of it."*

Before proceeding further I shall describe in a little more detail the beds below and above the Bala limestone.

From Cefn-coch, near Mallwyd, to the Bala fault, on the river Dee, from 2 to 3 miles east of Bala, the Bala beds above the limestone pursue for 16 miles a course as straight and regular as the limestone itself does between Dinas Mowddwy and Craig-yr-ogof. Their average strike is about N. 20° E., and their dip E. 20° S., from 40° to 60°. The angle rarely reaches 70°, and is occasionally lower than 40°, especially in the ground about Craig-ddu and Moel-fryn, west of Hirnant, where it flattens, and undulates eastward at angles of from 5° to 20°. The rock here principally consists of a fine-grained blue slate, sometimes arenaceous, and sparingly interstratified with beds of thin grit. Four

* "The small scale of the map had two inconveniences:—It seldom, by the features marked on it, enabled me to fix myself with sufficient accuracy when bearings or angular measurements were difficult to obtain, and it often rendered those measurements useless when obtained by not enabling me to protract them. Moreover, the portion of the surface occupied by the limestone and ash beds, as also the width of the faults, the size of the arrows for dip, &c., must necessarily be enormously distorted in order to render them discernible. The space actually occupied by the outcrop of the limestone was rarely more than 4 or 5 yards, while that taken by its representation in the map is never under 50, and very often equals 100. Were it drawn on a strictly natural scale it would be barely visible."

miles east of Aran Mowddwy these are overlaid by about 500 feet of grey felspathic grits and thin beds of interstratified slate, that perhaps may be on or near the horizon of the Lower Llandovery beds. These in turn are overlaid by the Tarannon shale and Denbighshire sandstones.*

Hirnant Limestone, &c.—Not one ashy bed occurs in this area above the Bala limestone, but a thin band of the Hirnant limestone of Sedgwick is found on the brow of the rocks called Trum-y-gwrageda, on the west side of the Hirnant valley, where a footpath crosses that ridge, and the same rock occurs at another spot in the valley, in a small quarry about a third of a mile west of Cwm-y-aethnen. It is fossiliferous, black, and pisolitic, the concretions being about the size of small grains of barley. When fractured they are both concentric and radiated, and in the centre there are frequently small rhomboidal crystals of carbonate of lime. The concretions are cemented in a crystalline base. This limestone, says Mr. Salter, "appears on two other spots on the "west side of the hill behind Aber Hirnant, near the road going "up to Maes-hir, but it is less developed, and consists principally "of calcareous nodules, which in one place were quarried for "lime. None of these patches are connected with each other, "nor could I find or hear of any other spots where they occur, "except at the Pass of Bwlch-y-groes above Llan-y-Mowddwy, "where Professor Sedgwick found loose fragments of limestone "in the same line of strike." The rock therefore scarcely deserves the name of a special limestone, although no doubt the detached portions are nearly, if not exactly, on the same parallel with that of Hirnant.

Fossils.—The beds beneath the Bala limestone are rich in fossils, and east of Aran Benllyn, at Tyn-y-fron and Tai-yn-y-nant, yielded the following species:—

Nebulipora favulosa, N. lens, Cythere umbonata, Homalonotus bisulcatus, Beyrichia complicata, Orthis alternata, O. flabellulum, O. elegantula, and *Leptæna sericea.*

In the neighbourhood of Bala lake the rocks are on the whole more sandy than slaty, and great surfaces of slab-like beds are in some of the quarries entirely covered with casts of *Orthis elegantula, Leptæna sericea,* and the rings of *Encrinite* stems all belonging to a single species, *Glyptocrinus? basalis.* There are also in many of the beds large tubes of annelides lying, some in horizontal and others in vertical positions (*see* Pl. 14). Star-fishes (*Palæaster*) are occasionally found, and *Trinucleus concentricus* and *Homalonotus bisulcatus* are the most prevalent trilobites. Corals are scarce, varieties of *Stenopora* or *Favosites* being almost the only species found. *Cystideæ*, though abundant in the limestone, have never been found in the beds above or below.

* Though foreign to the present description, it may be well here to state that these rocks are well shown on the turnpike road, and in the river bed east of Mallwyd, where they undulate with many contortions across 8 miles of country, and finally dip under the Wenlock shale near Garthbibio.

In the Bala limestone itself fossils become exceedingly numerous, and it is in many places chiefly composed of comminuted fragments of shells, corals, and trilobites, intermingled with more perfect specimens. A good example of this kind of structure occurs at Murddyn-marad, where there is also much false bedding in the associated shales, and ripple or current markings in the rocks below. The whole has a shallow-water aspect. The following species are among the most characteristic fossils of the limestone east of Bala lake:—

Corals:—*Nebulipora favulosa, Favosites fibrosa.* Encrinites. Trilobites:—*Calymene brevicapitata* and *C. Blumenbachii? Asaphus Powisii, Lichas laxatus, Trinucleus concentricus, Phacops apiculatus, Illœnus Bowmanni, Cheirurus bimucronatus* and *C. clavifrons, Homalonotus bisulcatus,* and *Beyrichia complicata.* Bivalve and Univalve Shells:—*Orthis vespertilio, O. calligramma, O. elegantula* and *O. testudinaria, O. Actoniæ, O. flabellulum* and *O. biforata, Strophomena grandis, S. tenuistriata, S. expansa,* and *S. rhomboidalis, Leptæna sericea,* and *Lingula ovata, Ctenodonta varicosa, Modiolopsis* and *Orthonota, Cyclonema crebristria, Murchisonia simplex,* and *Bellerophon bilobatus;* also *Orthoceratites.*

Immediately above the Bala limestone, fossils are numerous in many places, being usually of the same species as those in the limestone itself.

Fossils of Hirnant.—The fossils found in the Hirnant limestone consist of the following species:—

Orthis Hirnantensis, O. sagittifera, O. turgida, O. biforata (and varieties), *O. elegantula, O. testudinaria, Arca Edmondiiformis, Modiolopsis modiolaris.* With the exceptions of two first named, all of these are Bala species.

In the beds of the Bala series, immediately above and below the Hirnant limestone, fossils are exceedingly scarce, and the specimens are usually very imperfect.

Thickness of the Bala Beds.

It will be recollected that the porphyries and ashes of the Volcanic series, between Aran Mowddwy and Llanywchllyn, thin from 6,800 feet to 2,200 feet. The same kind of diminution may be remarked in the Bala beds.

According to the measurement of Mr. Selwyn, the thickness of the rocks between the upper ash of Aran and the limestone is 5,500 feet, and between the limestone and the Tarannon shale about 5,000 feet. This is immediately east of Aran Mowddwy (Plate 28, Fig. 3). According to Mr. Jukes's measurement between Moel-ddu, Moel Migynau, and Hirnant there is a thickness of only 4,000 feet between the volcanic rocks and the limestone, and 3,000 between the limestone and the Tarannon shale. Assuming these measurements to be approximately correct, it is evident that a great change in the thickness of these strata takes place in the course of 4 miles. Whatever may have given rise to it, this is significant. The whole thins out towards the north, and it is remarkable that the coarseness of the beds, and the increase of fossils in the Bala beds, bear a relation to this diminution in thickness, probably indicating a nearer approach to some old land of the Lower Silurian period.

CHAPTER XVI.

The Bala Beds, from Bala to Penmachno.

General Description. Bala Limestone.—I have now described the arrangement of the Lower Silurian rocks from the southward up to Bala Lake and the valley of the Dee. The great Bala fault, the south-western prolongation of which has been previously described, runs through the lake, and, accordingly, part of the strata of the south and east sides of the lake are repeated by the fault (which is a downthrow on the north-west), and re-appear on the west and north of the water.

Between Bala and Cerrig-y-Druidion we enter upon troubled ground, in that north-eastern part of the Merionethshire anticlinal which is marked by the sharp curvature of all the strata, in the ground between the Arenigs and Derwen.* When the geologist first attacks the country, he is everywhere met by conflicting dips, strikes, and unexpected patches of limestone and ash scattered hither and thither in apparently inextricable confusion, conveying the impression that not one or two, but many short beds of limestone and ashes are interstratified with the other rocks; and it was only by the expenditure of much labour and skill, that Mr. Jukes was able to dissect the main features of this intricate puzzle, and prove that all the limestones are parts of one and the same bed, and that there are only two lines of ashy strata.†

"It has been clearly ascertained that the Bala limestone and the limestone of Rhiwlas are the same bed; that the line of the Bala limestone previously described, after ending at Y-Garnedd, is taken up at Rhiwlas, 2 miles to the W.N.W., or in a direction at right angles to its previous general strike. If we supposed this dislocation to be the effect of one fault, and the mean dip of the beds to be 25°, it would involve a perpendicular downcast to the north-west of about 5,000 feet. Regarding this result as the effect of one principal fault, we have by no means the whole amount of fracture and dislocation that has affected the country we are now entering on. Several other faults of great magnitude can be traced in it, as well as numerous and strong flexures in the dip and strike of the rocks, producing a most singularly contorted and broken district. In describing this I will endeavour to condense the local details, and give, in as few words as I can, a sketch of that structure which required some months of hard labour to make out.

"In the first place, then, the rocks on the north-west of Bala lake, between the mouth of the Llafar and the Tryweryn, are precisely the same group of beds as those on the south-east side. They are composed of the same grey arenaceous slate rock, resting on the same black slates, which undulate with several flexures over the ground to the westward, until they finally crop out, resting on the traps of the Arenigs, precisely as they do to the southward on those of the Arans. The grey grits on both sides of the lake contain ash beds of precisely similar character. As

* Derwen lies about 12 miles N.N.E. of Bala.

† What follows in this chapter, between inverted commas, is by Professor Jukes.

we trace them to the north we find, as soon as the ground admits of it, that the limestone comes in above the upper ash bed at the same distance as it preserved on the east of the lake.

"The frequent repetition of the ash and limestone, always bearing the same relation of position to each other, and having the same strata below, between, and above them, establish their identity. These characters are too constant to be accounted for by accidental resemblances in different strata, while, unless they are supposed to be identical, the structure of the country becomes altogether unintelligible. By a fortunate chance a quarry was opened in the limestone of Rhiwlas, a mile north of Bala, while the district was being surveyed. Professor E. Forbes was himself present, and from this quarry a number of fossils were procured that have hitherto been found nowhere else."

Rhiwlas, &c.—The Bala limestone at and near Rhiwlas being unusually rich in fossils, I give a fuller list of them than usual, copied from the Survey List book. Those that are not found, or are very rare, south and south-east of Bala Lake, are marked with an asterisk.

CORALS.

Favosites fibrosa.
Chætetes (*Monticulipora*) *petropolitana.*

CRINOIDEA.

*Pleurocystites.**
*Hemicosmites.**
*H. rugatus.**
*Sphæronites munitus.**
*S. Litchi.**
S. .*
S. .
S. .
*S. punctatus.**
*S. pyriformis.**
Echinosphærites Davisii.
*E. granatum,**
Roots and stumps of *Encrinites*, some of them pentagonal and *Annelidæ* (*Serpulites.*)

BRACHIOPODA.

*Leptæna tenuicincta.**
*L. quinquecostata.**
L. sericea.
Strophomena rhomboidalis.
S. expansa.
Orthis Actoniæ.
O. elegantula.
O. simplex.
O. biforata, and others.
Lingula, sp.
L. ovata.
*Rhynchonella borealis.**

LAMELLIBRANCHIATA.

Modiolopsis or *Mytilus.*
Orthonota.
Ctenodonta varicosa.

TRILOBITES.

*Illænus Davisii,**
*Phacops Brogniarti ?**
Cheirurus bimucronatus.
C. clavifrons.
*Encrinurus sexcostatus.**
*Cybele rugosa.**
Trinucleus seticornis.
T. concentricus.
*Ampyx tumidus.**
Acidaspis .*
*Remopleurides Colbii.**
*R. longispina.**
*R. radians.**
Lichas laxatus.
*Agnostus trinodus.**
Asaphus Powisii.
Beyrichia, very numerous.

GASTEROPODA.

*Holopella conica.**
*Holopea lymnæoides.**
H. exserta.
*H. carinata.**
Murchisonia .*
Raphistoma .*
R. .*
Bellerophon bilobatus.
B. nodosus.

CEPHALOPODA.

*Orthoceras vagans,** and 5 or 6 others unnamed.*
Lituites cornu-arietes, and 2 others.
Cyrtoceras, several species.*

Bala Beds, Tarannon Shale, and Denbighshire Sandstone.

"Nearly directly north of the town of Bala, limestone is found at four places, Rhiwlas, Llwyn-y-ci, between Penmaen-isaf and Penmaen-gannol, and at Eglwys-Anne, places arranged on a line running about N. ½ E. and S. ½ W., and from one-third of a mile to a mile apart. At each place the limestone dips nearly south at from 10° to 30°; a person, therefore, merely walking from one to the other would at once set them down as four separate beds of limestone, and assign a very great thickness to the whole group containing them. It is found, however, that neither of the three first-named pieces of limestone can be traced along the strike for more than about 200 or 300 yards. They end abruptly each way. In each case, also, at almost precisely the same distance to the north of the limestone, namely, about half a mile, a piece of ash is found, likewise ending abruptly in both directions, likewise dipping to the south, and in all respects a counterpart to the limestone above it as far as the nature and slope of the ground will permit. Moreover, if we join the ends of each piece of limestone and ash by straight lines, those lines are very nearly parallel to each other, and if we produce them they touch the end of the next piece of ash or limestone below or above, as the case may be. In other words, these lines are faults, each of which is a downthrow to the north-east, and the portions of ground between them are narrow blocks, severed from the larger and more persistent portions of the same beds. We arrive at one of these larger portions at Eglwys Anne, whence the limestone may be followed continuously in a curved line round the north end of Moel Emoel, and down the valley on the east towards Bwlch-y-Tyno, and then along a more sharply curved and broken line to Creigiau-isaf. Half a mile to the north of the limestone a line of ash follows the same outline in all its curves. They both end in the same manner at a line running nearly north and south on the east side of Garw-fynnydd, and small detached fragments of both are again found dotting the country to the north-east along a probable line of fault, which runs thence to the south-west, and in that direction cuts off the Denbighshire sandstones near Llandderfel. There is thus immediately to the northward of Bala a broken trough, open to the south, the apex of which is at Pen-bwlch-gwyn, its western side being formed of the broken pieces before described, and its eastern side being formed of limestone and sandy slate, dipping west as far as Creigiau-uchaf. To the south of that point, however, or about Rhos-dawell and Moel-dryll,* neither limestone nor ash are to be found, the beds being thick sandy slates, with current or ripple mark often visible on their surfaces. They form altogether a bulky mass of very great thickness, dipping west at a high angle, and often absolutely perpendicular. I conclude the proper place of those Bala beds is somewhere above the limestone, and believe that a fault running about W.N.W. and E.S.E., runs somewhere at the northern end of Rhos-dawell and between it and the limestone.†

"Returning to the north end of the trough before described, the line of the Llandderfel fault would pass, if produced, just north of the ash of Pen-y-bwlch-gwyn. This fault seems to branch first about a mile north-west of Llandderfel, and again on the southern slope of Moel-y-Darren, the intermediate pieces of rock being thrown down to the northward. We accordingly find the evidence of its continuance thus far in a recurrence of the ash bed, with nearly the same contour as on the ground to the northward of it, but modified by the shape of the country. From each end of this piece of ash also smaller fragments are let in between cross fractures. Thus far, or from Bala to Y-Gesail, the dip of the rocks along the centre or axis of this rudey trough-shaped piece of country has been uniformly south. On Y-Gesail, however, it flattens to the north, and for about half a mile the beds are as nearly as possible horizontal, and then begin to dip gently to the north. From this dip it results that a considerable and very conspicuous outlier of the ash is found on the summit of Craig-y-llwynog, and on the opposite side of the valley, or about Gelli-oedd and Llechwedd-fign, it dips under the country to the north.

* From a mile to two miles north and north-east of Bala.

† The great faults which on the western side of the trough run about north by west and south by east must necessarily have one cross fracture or more somewhere; it is possible the fault running across the northern end of Rhos-dawell may serve this purpose.

"We have in this description the appearance of a broad anticlinal curve, the centre of which is Y-Gesail, from which the beds dip north and south respectively; this is true so far, but the anticlinal line is a very short one, the beds from under it, while they dip north and south, rising pretty rapidly towards the east and west respectively, and thus making a mere saddle rather than a long ridge. The anticlinal curve is in fact a part of the great Merioneth anticlinal, the minor fractures and contortions being due to mere local disturbances."

"To see this more clearly, let us shift our point of view. The beds of ash and limestone of Pen-y-bwlch-gwyn and Moel Emoel, after striking for some distance to the north-east, and being shattered by the Llandderfel fault, recover something of their old strike on the north-east side of it, and run north-east for some distance, with a pretty high dip to the south-east. They are, however, much broken by faults, and the limestone has especially suffered, since it only makes one poor appearance about Llwyn-onn, and is never afterwards seen till we reach Pont-y-glyn-diffwys, on the Holyhead road. It is probable, however, that its disappearance is not wholly due to its being concealed by faults, but in part, perhaps, to its thinning out or parting with its calcareous matter and fossils, so as to be no longer distinguishable. The principal ash bed below it runs on for some distance, and is very well shown round the north end of Pen-y-cerrig-serth and in the valley to the north-east, when it disappears, or at least cannot be traced at the surface. Another ash bed, however, which comes out at a still lower level, and which is of a lighter colour and more flaky character, can be traced on down to Llwyn-Saint on the north-east, and in the other direction is found to form a broken curved line by Ty-newydd, the top of Cwm-da, Y-foel-goch, Fridd-gwan, and Hendre Garth-meilio. It thus partly surrounds the village of Llangwm, viz., on the south-east, south, and west sides, and at every place dips from that village as a central point, passing under the upper ash, which equally surrounds the village at a greater distance. Now the outcrops of these two ash beds keep at a considerable distance from each other in the space described, except at one point just north of Pen-y-cerrig-serth; it might be imagined, therefore, there was a great thickness of rock between them. I believe, however, this appearance is due to dislocations and the nature of the ground. This is rendered probable, because on the north-east of Llangwm, across the Holyhead road, two ash beds occur on the sides of the steep cliffs, with no great thickness between them. These ash beds are likewise much broken by faults, which rather, however, dislocate and disturb the dip of the beds than produce any great amount of upthrow or downcast, and render it difficult to say what is the general strike and dip of the mass, except from that of the beds above and below them. Guided by this, we may say that these ash beds dip at first east or north-east, passing under Cader Dinmael, and then curve over and dip to the north-west, in which direction, after being brought up again once or twice to the surface by faults, they finally disappear just beyond Hendre Arddwy-faen. We now have the village of Llangwm entirely girt by a circle of ash beds, except about 50° of the circumference between W.N.W. and north by west, and find that the dip of the beds is on all sides from Llangwm as a centre. There is nothing in that neighbourhood to account for this circumstance, neither do any beds appear there which could be identified very strictly with the black slates that lie just above the traps of the Arenigs and Mynydd-nodol. The surrounding faults must necessarily traverse this spot also, and probably continually reproduce the same beds at the surface as is their effect elsewhere. The broken dome-shaped form thus assigned to the rocks around Llangwm is merely the result of a local intensity of force, the centre of which is on the axis of the great Merionethshire anticlinal.

"If now we trace the superior rocks, viz., the Tarannon shales and Denbighshire sandstone, we shall find them describing a curved line generally parallel to the curve now assigned to the ash beds. After crossing the river Dee, they run nearly in a straight line N. 35° E. for rather more than 8 miles, or to the banks of the Clwyd between Bettws-gwerful-goch and Derwen. Their dip is from east to south-east, at angles varying from 15° to 50°.

"At a very short distance to the westward of this boundary, however, the mass of the beds are in a very different position, and dip almost invariably south at a very high angle, varying from 40° to 80°. This is most remarkably

the case in a band of country about a mile wide and 4 miles long, stretching from the Llandderfel fault to the Holyhead road near Maes-mawr. The position of the rocks here is most anomalous, since they strike towards the ash beds on the west and the Denbighshire sandstone on the east, dipping south at a mean angle of about 60°; yet, as a group, their range is north-east by north, and neither ash beds nor limestone, nor any known lower rocks, can be found among them. I can only explain their structure by supposing a number of faults more or less nearly east and west, causing frequent downthrows to the north, so as to bring in a recurrence of the same beds in that direction. That faults of some sort exist is shown in several places by large masses suddenly striking at right angles to each other, sudden changes of dip at very high angles, and other similar signs of dislocation. When we reach the Holyhead road we at last find the limestone well exposed in the gorge of Glyn-diffwys. It here exhibits its usual characters, having a bed of black crystalline limestone for its base, above which are some banded concretionary beds; these concretions are, however, larger than usual, the beds thicker, and the whole calcareous mass of much greater importance than it generally exhibits. Calcareous matter extends also into the slates above, so that there is a thickness of what may be called limestone here of about 50 feet. The beds are much broken, dipping at one place south-east and then south-west at 50° and 60°, and finally about south by east at 70°, with which dip they strike along a part of the Holyhead road for nearly half a mile. At the eastern end of the wood under Gros-faen the calcareous beds are suddenly lost, but on the hill-side to the northward above Tyn-y-bryn highly fossiliferous beds with some calcareous concretionary patches are found, dipping to the south-east and east; and, following these along the strike to the northward, a patch of limestone is formed near Hafodty-gader, dipping east at 30°. Immediately north of this spot a rotten arenaceous slate is seen dipping north at 5°, but nearly a mile to the westward the Bala limestone is again found in full force, with all its usual characters, on the top of Cader Dinmael. It is, as usual, both contorted and broken by faults, so that in one place there might be supposed to be two beds of it: its general dip, however, is north at about a mean angle of 10°. To the westward the limestone is suddenly cut off, apparently by a fault, and is never again seen in the neighbourhood in such a form as to be recognized. It will be seen that, notwithstanding its broken condition, a line drawn through the detached pieces of limestone will conform in shape very nearly to the line drawn through the broken ash beds below it.

"In order to mark the upper boundary of the Bala beds I shall here briefly describe the passage of the Tarannon shales and Denbighshire sandstone in their curved course across the great Merionethshire anticlinal.

"The upper beds of the Bala series, after crossing the Holyhead road about Maes-mawr, still retain their high southern dip for some distance but with greater irregularity. About Bettws-gwerful-goch a large mass of them dips regularly to the south-east under the Tarannon shales and Denbighshire sandstone at an angle of 60°. Farther north, however, at Ty-cerrig, the Bala beds are faulted against the overlying strata, but in addition to this there is evidence of a well-marked unconformity, as about Dyfannau the dip of the Bala beds is north at 20°, while the Tarannon shale and Denbighshire sandstone dip nearly east or east by north at about 30. Where the Denbighshire sandstone crosses the Clwyd, about Tyn-y-coed, some well-marked beds of conglomerate strike directly across the river, dipping east at 45° for half a mile on each side, but further north the beds flatten rapidly, begin to dip more northerly, and the boundary curves to the north-west and about Pont Bod-Reuail, where it again crosses the Clwyd, the general dip is north-east at 20°, with a small local curve to the east, but very shortly a wide and general dip to the north sets in at a not greater angle than 15°. The boundary of the formation then strikes west to the meridian of Cerrig-y-Druidion, and the formation spreads to the northward with several gentle undulations, dipping north and south at about 5°. Throughout this course a narrow band of Tarannon shale separates these sandstones from the upper part of the Bala beds. The upper Bala beds, after suffering one or two sharp flexures to the northward of Bettws-gwerful-goch, causing them to dip in various directions at angles often equalling 70°, likewise acquire gradually a northerly dip; and on Y-Graig-wen, Derwydd, in the bed of the Alwen, and thence to Cerrig-y-Druidion dip always between north and

north-west at angles varying from 5° to 20°, the lesser angle being always the nearer to the boundary of the Upper Silurian rocks.

"We have now traced all the beds, from the lower ash bed to the Denbighshire sandstone, round the sweep of the circle which has Llangwyn for its centre, except over a space occupying about 50° of that circle, to the north-west of Llangwm. The two principal defects in the description of the district arise from the absence of the Bala limestone in the space between Llwyn-onn and Pont-y-Glyn-diffwys, and in that between Cader Dinmael and Cerrig-y-Druidion. That absence may be due either to faults, or to the dying out of the beds, or to both conjoined. Quite sufficient evidence remains to show that the strata have been raised into the position of a fractured dome, of which Llangwm is nearly in the centre. When, however, we come to examine the slice of country included in the angle of 50° just mentioned we find ourselves entirely at fault, from the almost total absence of all evidence as to its structure. Neither ash bed nor limestone is to be seen, and over the greater part of the space the boundary of the Denbighshire sandstone is utterly illegible. At a place about a mile and a half north-west of Langwm, near Hendre-wen, are a few small quarries, in which the usual fossils of the Bala limestone, and also many specimens of the *Rhynconella navicula* were found; there were also a few calcareous nodules. It had, however, no sign of the usual mineral character of that bed. The country around it, and all to the north-west, is so covered with drift that it is rarely a piece of rock *in situ* shows itself. Along the south side of the ridge, running W. ½ S. from Cerrig-y-Druidion, a little rock is seen, commonly an arenaceous flaggy slate of precisely the same lithological character as that to the eastward of Cerrig-y-Druidion, which dips towards the Denbighshire sandstone. The north slope of this ridge is buried under an immense accumulation of drift extending from the flat of Merddwr almost to the summit of the ridge. About a mile north of Cerrig-y-Druidion the Tarannon shale and Denbighshire sandstone boundaries suddenly turn southerly, and the beds dip west at 50°, but very shortly curve back again, and by Ty-tan-y-foel dip north, with slight undulations, at about 5°. With this inclination the boundary sinks into the flat of Glan-y-gors. West by south from this spot the Denbighshire sandstone is seen suddenly to rise up the side of the hill called Garn Brys, and beds of coarse conglomerate, belonging to that formation, are shown very conspicuously on the summit of that hill, dipping N. 30 E. at 25°." On the south this rock is in contact with beds far below the Bala limestone, and it will presently be shown that the disposition of the rocks of this neighbourhood is probably partly to be accounted for by faults.

"In previous descriptions* it has been stated that, when not faulted, the black slates wrap round the upper ashes of the Arenigs and Mynydd Nodol. To the south-east and east they dip under the country which has been already described. On the north-east they dip from the ash of Craig-ddu towards Moel-cwm-maen, on the south flank of which the two Bala ash beds are shown in a less broken condition than usual, the upper one being the equivalent of the ash that underlies the limestone of Moel Emoel, and the lower that of the flaky ash near Langwm. Farther to the north the ashes are again a good deal fractured, notwithstanding which they turn round conformably to the general outline of the Arenig ash, and dip north from Garnedd-filiast towards Garn-Brys and Copa-ceiliawg. On the hill side south of Blaen-y-cwm there is a very thick flaky ash bed of precisely the same character as that which surrounds Llangwm, and which, after dipping west at Hendre Garth-meilio, and passing under Pen-y-Gob, Lechwedd-fign, and Moel-cwm-maen, reappears with an easterly dip about Defeidty-isaf and Cader Benllyn. The upper ash of Moel-cwm-maen can be still more easily identified with a long piece that from near Bwlch-maen-melin runs up to Copa-ceiliawg with a gentle dip to N.N.E. Now, in following the strike of these two pieces of ash, we are in each case led to detached beds of trap, differing in structure from the ashy beds heretofore described. The lower ash strikes directly for a piece of trap seen in the brook of Cwm-gylchedd, and, but for a probable fault, might doubtless be traced into it. The upper ash is lost under bog and earth on one flank of Copa-ceiliawg, but precisely in its strike on the other side of the hill is a bed of hard compact

* Pp. 66 to 70, and Chap. 14.

felspathic trap, with a few dispersed crystals. The lower piece of trap in Cwm-gylchedd appears to be much thicker than the lower ash, but is only to be seen in the bed of the torrent. The upper trap is very little thicker or more massive than the upper ash, resembles it exactly in external appearance, and continues in the same strike for half a mile, dipping north at 30° till it reaches the brook running down towards Cerrig-cellgwm-isaf."

Now, on looking at the map, it appears that the Tarannon shales are absent on the east, south, and west of the promontory of Denbighshire sandstone that lies between Pentre Voelas and Garn Brys. Up to this point these shales have been constant, and they again appear in their usual position for a brief space towards Llanrwst, and further north between Llanbedr and Conway, where no fault interferes to cut them off. Further, experience shows that in this neighbourhood, and indeed everywhere in North Wales and Shropshire, they immediately underlie and are conformable with the Wenlock shale, of which the Denbighshire sandstone forms the base, and it is therefore most unlikely that at this point the sandstone should suddenly overlap them. But north-east of Garn Brys the Bala beds and Denbighshire sandstone strike directly at each other, and this can only be accounted for by a north-east fault.

"On the south side of Garn Brys the upper ash is but a very small distance removed from the boundary of the Denbighshire sandstone, and as the beds dip at only slight angles there cannot possibly be room for the outcrop of the Bala limestone and superior beds between the two. Either then there is a fault, or the Denbighshire sandstone has crept suddenly and unconformably over the outcrop of the Bala limestone, and covered it from view." The latter supposition is at variance with the behaviour of the rocks of the neighbourhood, and it being certain that the Tarannon shales are also absent, it seems probable that the Denbighshire sandstones are thrown by a north-west fault against a low part of the Bala beds between Garn Brys and Plas Uchaf, near Yspytty Evan. "On the supposition of unconformity we should probably find the Bala limestone reappearing from under the Denbighshire sandstone somewhere farther on if we followed its boundary. Now in following the brook called Afon Clettwr, a little beyond the bridge of Pont Clettwr, we find some large blocks of Bala limestone almost if not quite in situ, and the Denbighshire sandstone capping the hills above at Ty-newydd. This evidence is rather in favour of the supposition that the Denbighshire sandstone has crept unconformably over the Bala beds. But there must also be some fault or faults to account for the relations of the two between Plas-Uchaf and Pentre Voelas."

The same evidence of conflicting dips and general absence of Tarannon shales (except in one spot, which strengthens the proof) give strong presumptive evidence of a fault which throws down the Denbighshire sandstone on the north-east against the Bala beds between Pentre Voelas and Hendre-wen, near Llanrwst, and also on the east under the alluvium of the Conwy between Hendre-wen and the country 2 miles south of Caerhun.

"From the Clettwr the limestone is not traceable in either direction on account of the drift and other superficial covering; but a quarter of a mile south of Yspytty Evan, near Ty-nant, calcareous beds are seen, which strike for the river Conwy, a little above the village. Here the limestone is found in its most characteristic form, and is traceable thence up the hill by Hafod Evan, when it seems to spread on the hill side, and thence turns down again into the Conwy opposite Craig-ddu. It thence again strikes up the hill above Pennant, and is well shown on the moors above the wood, when it appears suddenly to end, dipping east at an angle of 25°.

"Its next appearance is about a mile north of this spot in the brook south of Blaen-eidda-isaf, and then on the hill side above Tyn-y-graig, dipping E.S.E. at 25°. It is traceable thence to a line of quarries which run over some hills north of a moor called Pen-llech. In these it is excellently shown with all its usual characters, and runs down, with some contortions, into a large wood between Penrhyn-uchaf and Dylase-isaf. It is here lost sight of, but is again found on the opposite bank of the Conwy, running for about half a mile to the N.N.E. by the house of Berthidion. Between this spot and Llanrwst no trace of it has been found.

"We have previously traced the course of the lower rocks containing the ash beds up to the river Clettwr. I will now briefly describe their further extension.

"In the first place regular ash beds are not met with anywhere round the valley of Yspytty Evan. In their place, however, and about the same distance below the limestone, occasional masses of a very singular rock are found. This has a felspathic base, sometimes hard and compact, at others flaky—in the one case like a trap, in the other like an ash. It is crowded with round concretions varying from the size of a pea to that of a man's fist. In some cases these form a mere nodule of compact rock like the base, but in others they are regular agates with concentric coats and a crystalline nucleus. This rock does not occur in regular beds, but in roundish lumps and bosses, sometimes not more than 10 yards, sometimes as much as 100 in diameter. The bosses do not appear to produce any confusion in the adjacent beds, but appear as contemporaneous as the ash beds. This is farther shown by their occurring always along a certain horizon at a regular distance from the limestone, the line of the two always running parallel in all their curves over the country. Thus the line passing through these bosses runs along the hills south of Yspytty Evan on the right bank of the Conwy, parallel to the limestone, crosses the river about half a mile above Pennant, and then by Blaen-eiddew-uchaf up to Penllech, where it forms the very conspicuous bosses of Carn-y-parc, &c., and thence down to the Conwy at its junction with the Machno. This curved line evidently marks the existence of a rude synclinal depression, the axis of which runs about N.N.E. in, or parallel to, the valley of the Conwy about Yspytty Evan. This depression, however, can only be indicated approximately, for the whole of the country on both sides of this part of the Conwy between Pentre Voelas and Dinas House has been violently disturbed, and the rocks now lie in great confusion at all angles and in all positions. Several small anticlinal and synclinal lines can be traced in them running due east and west, with the rocks dipping north or south at 70° and 80°. In several places the beds are vertical, striking east and west, while close by the same beds may be seen dipping in various directions at no greater angle than 5° or 6°."

It will be recollected that one or two places were mentioned in the neighbourhood of Bala, where a crystalline ash bed was found about 30 or 40 feet below the limestone. This is possibly represented in the Penmachno district by a very considerable bed of contemporaneous felspathic irap, lying just below the limestone on Penllech, and near Berthidion. It is in some places at least 50 or 60 feet thick, but thins out to an ash bed of about 10. It is sometimes nodular or concretionary.

From the junction of the Machno and the Conwy, to which we had brought the nodular ash or trap mentioned before, we may trace it still half a mile or a mile to the north-west, where it forms a large and imposing mass called Bryn-y-ddinas. From this, another series of great bosses and masses of the same rock may be traced to the south-west, along the top of the ridge forming the south-east bank of the Llsder, and thence to Ro-llwyd and Ro-wen, the two highest points between Penmachno and Dolwyddelan. This curved line running along both sides of the valley of the Machno shows it to be occupied by a rude anticlinal arch, the axis of which runs N.N.E. and S.S.W., parallel to the synclinal line of the valley of the Conwy near Yspytty Evan. This is corroborated (if need were) by the position of a faulted ash bed, west of Penmachno, which represents the lower ash of Cerrig-y-Druidion and Bala, or, at all events, is very near its horizon. It is much broken; but a line joining its detached portions would run from the ease side of the Machno, near Bryn-y-grug, through the village, and thence up the valley of Glascwm, forming a smaller and inner curve parallel to the outer and larger one of the nodular trap above, and parallel also to the general outline of the broken curve of the Llyn Conwy and Manod ashes below.

CHAPTER XVII.

THE COUNTRY BETWEEN THE MANODS AND MOELWYN, MOEL SIABOD, AND NANT GWYNANT.

General Description.—The Bala beds have now been described from the neigdbourhood of Dinas Mowddwy to the heights between Penmachno and Dolwyddelan. I shall continue this description through the slaty region that lies between Moelwyn Nant Gwynant, and Moel Siabod, leaving to succeeding chapters the great mountain range that lies between the Conwy, Traeth-mawr, and the Menai Straits.

North of Moelwyn and the Manods the slaty rocks dip north and north-west, plunging under the felstones and calcareous ashes of Dolwyddelan and of the equivalent traps of the Snowdon region south and south-east of Llyn Gwynant and Llyn-y-ddinas. The slates are associated with numerous lines of hornblendic greenstone, which for the most part lie more or less between the beds, and are proved to be intrusive by the alteration of the strata in contact with them both above and below. In their higher beds near the felstones the ordinary strata are often sandy, and yield numerous fossils of the ordinary Bala species.

Both physically and palæontologically the proof is clear that these are equivalents of the Bala beds, and of the Caradoc sandstone of Shropshire, and that the calcareous ashes of Dolwyddelan are the actual representatives of the Bala limestone; and in succeeding chapters it will be shown that this leads to the startling conclusion that all the vast masses of ashes that crown the felstones of Snowdon and Moel-Hebog are but an enlarged development of the same strata.

From the Moelwyns to Nant Gwynant.

North and north-west of the Ffestiniog slate quarries for about a mile, the rocks principally consist of blue slate. On the Moelwyns above the felstones there are beds of good quality, dipping north-west at angles of about 40°. The dip of the cleavage is a few degrees higher. Higher in the series, the quality of the slate seems to deteriorate. When weathered it is then of a dull rusty brownish colour, and when freshly split dark blue or bluish grey. The beds are beautifully exposed on the slopes of Yr-allt-fawr about a mile north-east of Cwm Orthin, and from the Ffestiniog and Dolwyddelan road massive beds of these strata may be seen piled on each other, dipping steadily north at angles from 40° to 60°. On the west side of Cwm Orthin, about half a mile north of Moel-y-rhudd, just about the top of the dark slates that are believed to form the Upper Llandeilo strata, a few short thin hard felspathic ashy bands are interstratified with the slate. They represent the last dying away of the thick bedded ashes of Llyn Conwy and Migneint. The beds are somewhat contorted, and greenstones partaking of these contortions are intruded among them, alike altering both ashes and slate, the latter in the crags that overhang the brook south-east of Bwlch-cwm-Orthin being changed into a kind of dark Lydianstone.

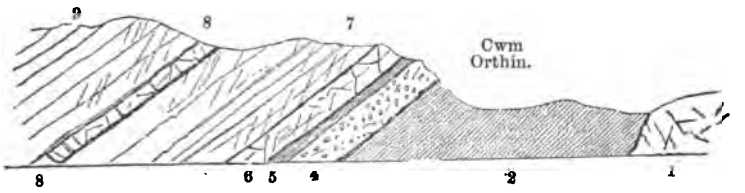
Between Moelwyn and Cynicht the slates have been described by Mr. Selwyn as "blue and grey argillaceous and arenaceous slates, with occasional thin "bands of fine-grained grey and brown sandstone."*

* Horizontal 6-inch section, Sheet 28, line 3, to which great part of this chapter generally applies. Also Plate 28, No. 3.

On Cynicht *Homalonotus bisculatus* was found and other Bala fossils in the neighbourhood. Good sections are seen on the hills round Llyn-conglog, on Cynicht, and on the road between Llanfrothen and Beddgelert. The surfaces of the beds are often ripple or current marked, and the beds occasionally undulate, as for instance around Llyn-coch, and on the road north of Llanfrothen. The general dip is however north-westerly at angles varying from 25° to 50°. In general the cleavage dips in the same direction at angles of about 70° to 80°, but about a mile north of Llanfrothen it strikes more northerly, and is often nearly or altogether vertical.

One line of felspathic trap somewhat hornblendic intersects these rocks on the north side of Cwm Orthin, in the manner shown in the following diagram, which represents the general arrangement of the strata on a north-west line between the syenite of Ffestiniog and the top of the hill that bounds Cwm Orthin on the north-east.

Fig. 28.



1. Syenite.
2. Speckled Tremadoc felspathic and talcose flaggy beds.

Llandeilo and Bala beds.

3. Arenig grit and slate, mostly altered and speckled.
4. Felspathic ashy conglomerate.
5. Arenig slate.
6. Felspar porphyry.
7. Blue Arenig slate of the slate quarries.
8. Felspathic trap.
9. Blue slaty Bala beds.

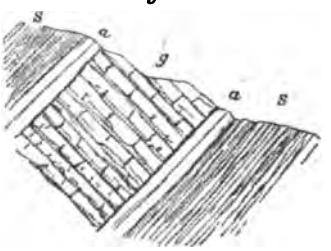
In places the trap No. 8 is slightly hornblendic; and though probably intruded between the beds, it may possibly be a regularly interbedded lava-flow. Besides this there are many eruptive courses of greenstone north of the Moelwyn range (Plate 28, Fig. 3), forming part of a series that has been intruded into the Bala beds between Traeth-mawr and the west side of Cwm Penamnen.* Like others of their class in North Wales they show a general tendency to conform to the strike of the country, but in spite of this the circumstance that they sometimes almost imperceptibly cross it would alone suffice to prove their intrusive character, and their occasional more irregular branchings would place this beyond a doubt, even without the more direct evidence of the alterations they produce on the slaty rocks in contact both with their under and upper surfaces. Altogether they form a marked feature in the district, cropping out in the 10 miles of hills that range between Traeth-mawr and Cwm Penamnen in more than 40 spots and bands, some of which are several miles in length. Partaking of the contortions that have affected the whole country after their intrusion, it is possible that some of them may join not far beneath the surface, and only rise in different horizons by cutting slightly across the beds underground. Good examples of the effects of the undulations of the strata on the greenstones may be seen in the country immediately north of Moelwyn and west of Cwm Orthin, where, in an irregular manner, they follow all the twistings of the strata into which they have been injected. A striking example also occurs on Castell, between Cwm Orthin and Llyn-y-Ddinas, where the greenstone alike cuts across the strike, and partakes of the contortions of the country (Plate 28, Fig. 3). For about two miles to the north-east, near Llyn-Edno, this greenstone is separated from the body of that porphyry by a considerable thickness of strata dipping north-west, about 25°, the greenstone also dipping approximately with the beds.

* Cwm Penamnen lies about five miles N.N.E. of Ffestiniog, on the way to Dolwyddelan.

Were the greenstone perfectly interbedded it would pass regularly under the outlier of Castell on the east and south, instead of which it passes *through* it and again rises with a western outcrop north of Cwm-celli-Iago on the opposite side of the axis.

At the north end of the neighbouring outlier of Yr-Arddu one of these injected masses is crystalline and felspathic, rather an unusual circumstance with the linear injected rocks of North Wales. Rarely they seem to pass from felspathic into well crystallized hornblendic greenstone, as for instance in the band, over five miles in length, that runs from Careg-hylldrem,* north-east under the steep slope of Cynicht to Llyn-coch. Some are markedly crystalline, such as those of Moel-y-gest and the cliffs near Tremadoc, and the island-like hills of Hir-ynys and Garth that rise through the alluvium of Traethmawr. Finer examples still occur on the cliffs that partly bound the secluded tarns of Llyn-llagi and Llyn-adar,† where the slate in contact with them is altered into a spotted porcelanic substance, such as is sometimes termed "snake-stone." This is frequently the case with slates that lie close to the greenstones of Caernarvonshire, and in such circumstances they are often quarried for hone-stones. Some of the greenstones are nearly amorphous, and they are also in this area occasionally columnar, as on Craig-y-llyn-llagi, Bwlch-y-batel,‡ and by the north-east angle of the felstone porphyry of Yr-Arddu, where the columns of hornblendic greenstone lie at right angles to the dip.

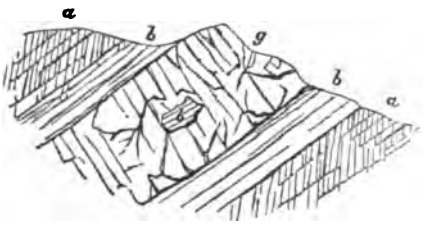
Fig. 29.



g. Greenstone. *a*. Altered slates. *s*. Unaltered slates.

Good examples of the greenstone and its effects may be seen on Moel-dan-nogen and at Bwlch-y-gerddinen on the road from Ffestiniog to Dolwyddelan. The rock is an ordinary diorite or greenstone, very hornblendic, and largely crystalline, and the slates both above and below the mass are porcelanised, flaky, and speckled like "snake-stones." Some slaty included fragments are also speckled, and others, which like these have been caught up and included in the greenstone during this intrusion, have the appearance of felspathic trap. The slates all round are highly cleaved, with the exception of the bands in the immediate neighbourhood of the greenstone.

Fig. 30.



a. Cleaved slate. *b*. Altered slate uncleaved.
g. Diorite with included fragments of slate *b*.

* By Traeth-mawr 1¼ miles north of Llanfrothen.
† Between three and four miles east of Beddgelert.
‡ Three miles E.S.E. of Beddgelert.

This greenstone, like others of its class, was intruded into and altered the slates before those disturbances took place that heaved and contorted the strata into their present inclined positions, and also produced the cleavage; and it is clear that the altered porcelanic character of the rocks in contact with the greenstone prevented their being cleaved. If, as I believe, cleavage has been produced by intense lateral pressure during disturbance of the strata, then it would appear that the excessive hardness and compactness of the altered rocks in this instance hindered the particles from being re-arranged so that their major axes should lie in lines at right angles to the pressure, thus originating a tendency to split in a certain direction, which constitutes cleavage; whereas in the softer rock this change of position of the particles was readily produced.

Dolwyddelan.—Further to the north and west, the great *upper* interbedded series of felspathic lava and ashes come on, forming great part of the high mountain district of Caernarvonshire from Conway to Criccieth on Cardigan Bay, and of which Snowdon may be said to be the centre. North of the *lower* volcanic series of Manod-mawr near Ffestiniog, these first appear in the valley of Dolwyddelan in the manner shown in the following diagram which explains the general structure of this country and especially illustrates the circumstances that thick accumulations of slate separate the igneous rocks of the Arans, the Manods, and Moelwyn from those of Dolwyddelan and Snowdon.

Beyond the Moel-dannogen and Moel-farllwyd greenstones (*g g* of Fig. 31) the Bala beds dip steadily towards the valley of Dolwyddelan at angles ranging between 20° and 60°. They consist of arenaceous slate and sandstone, and are generally fossiliferous, especially in the upper part of the series approaching the traps and ashes of Dolwyddelan. The strata are all more or less cleaved, the cleavage following the general strike of the country, and like the beds (but often at higher angles) dipping northerly at angles of from 60° to 70°. The following are the common fossils of the neighbourhood :—

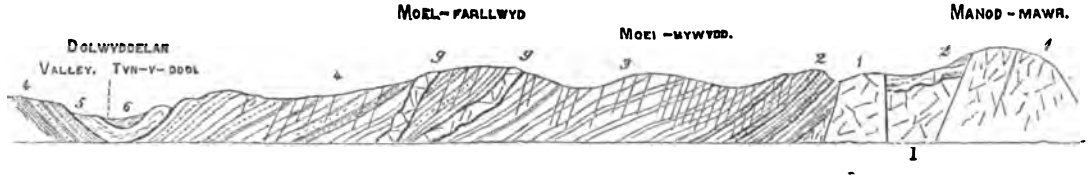
Nebulipora lens; Asaphus Powisii, Homalonotus bisculcatus, Cythere umbonata, Orthis flabellulum, O. calligramma, O. elegantula, and *O. vespertilio, Strophomena expansa, S. grandis, Leptæna sericea, Orthonota quadrata, Ctenodonta lævis, Murchisonia simplex,* and *Bellerophon bilobatus,* &c.

The igneous rocks of the valley of Dolwyddelan lie in an elongated basin ranging from Yr-Arddu on the west to Y-Fedw on the east. On the south, the Bala beds dip under them at angles varying from 45° to 80° near Hendre; and on the north, on the slopes that rise towards Moel-Siabod, the same rocks dip southerly at similar angles. The trap consists of blue felstone weathering grey or yellow, and it is partly overlaid by and partly includes a mass of dark blue ferruginous slate, the cleavage of which follows the strike of the country, and is nearly vertical, or dips southerly 80°. The bedding is obscure but probably dips north, and the rock has been worked for slate in several places between Dolwyddelan and Tyn-y-ddol. The branching manner in which the felstone is associated with this slate might at first sight seem to indicate its intrusive character; but it can be easily imagined how successive submarine flows of lava might coalesce at one end, while interstratified mud was deposited on other parts

Fig. 31.

SECTION ACROSS THE BALA BEDS FROM MANOD-MAWR TO DOLWYDDELAN.

N. S.



1. Lower felspathic porphyry of the Arenig series, the equivalent of the Arans, Arenig, and Moelwyn.
2. Blue slate and felspathic ash between two faults, including part of the Ffestiniog slate quarries - - - - - - - - - } Llandeilo beds.
3. Blue slaty rocks - - - - - - - - -
4. Slate and sandstone, very fossiliferous - - - - - -
5. Upper felspathic porphyry and ash of the Caradoc or Bala beds - - - } Bala beds.
6. Calcareous fossiliferous ash, the equivalent of the Bala limestone. 5 and 6 are equivalent to the rocks of Snowdon, Glyder-fawr, Moel-Hebog, &c. - -

g. Greenstones often intruded in the lines of bedding.

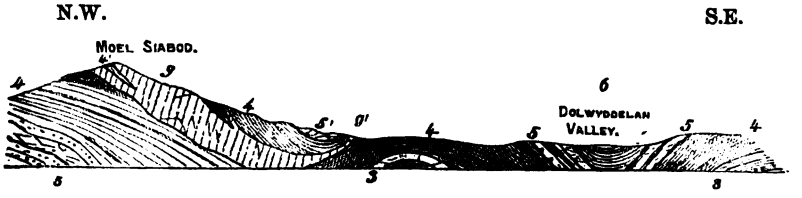
of the lava current in the intervals of eruption. Besides this, the felstone is regularly overlaid by a highly calcareous brown ash between Castell-Dolwyddelan and Yr-Arddu; and this rock (except that it is often more calcareous) is identical in structure and position with the ashy beds that overlie the interbedded felstones of Snowdon, Y-Glyder-fawr, and Moel-Hebog. This ash is in places fossiliferous, somewhat felspathic or sandy, and conglomeratic, containing pebbles as large as an egg, and sometimes so very calcareous that it weathers precisely like portions of the Bala limestone on the south-east and north of Bala. From its position and lithological character, Mr. Jukes, Mr. Selwyn, and myself were all of opinion that it is the actual representative of that limestone itself. Diagram No. 31 shows that it occupies the same general position with reference to the Manod and Moelwyn porphyry that the Bala limestone does to those of Aran-Mowddwy and the Arenigs; and the felstone and felspathic ash of Dolwyddelan may be considered as the general representatives of the ash that lies close beneath the limestone in part of the Bala district, or more especially of the felspathic rock that immediately underlies the same limestone on Pen-llech, about two miles east of Penmachno.*

The thickness of the beds between the two sets of strata is in both cases approximately the same, and it will be observed that in both districts the upper portion is sandy and fossiliferous, the lower beds being formed of dark blue and generally unfossiliferous slate, may possibly represent the Llandeilo flags, but with greater propriety may perhaps be considered as forming the lower part of the Bala beds, between which and the underlying Arenig slates there is no definite lithological boundary.

Moel Siabod.—The same set of strata are continued on the north and north-west in broad anticlinal and synclinal curves to Moel Siabod as shown in Fig. 32.

Fig. 32.

SECTION ACROSS THE BALA BEDS FROM DOLWYDDELAN TO MOEL SIABOD.



3. Felspathic porphyries, Lower.
4. Grits and slates, fossiliferous, Bala beds.
5. Felspathic porphyries, Upper - - - { Equivalents of the porphyry
6. Calcareous and felspathic ashes, Bala beds - { and ashes of Snowdon.
g. Intrusive greenstone.

* Six-inch horizontal section, Sheet 31, line 4.

Between Dolwyddelan and Moel Siabod the fossiliferous beds, No. 4 of the diagram, rising in the moorland from beneath the igneous rocks of the valley, roll over to the north, about half-way up the mountain, and the felstone No. 5′ is caught, in two small patches, one of which is shown in the section, in a kind of inclined basin, which runs from the south-west of Moel Siabod to Llanuwchlyn on the left bank of the Conwy.

The higher part of Moel Siabod is formed of a great mass of intruded greenstone (*g*), often columnar, which forms the crags that overlook Llyn-y-foel, in the deep recess on the eastern slope of the mountain. On the south-west this greenstone commences near Llyniau-duwaunedd, and branches into two at the summit, where the slaty rocks are highly altered between the forks (No. 4′). The longer branch strikes north-easterly, and crosses the Holyhead road near Dolbryn. The whole dips to the south-east, and cutting across the beds, again rises in the synclinal curve on a slightly different horizon in the long strip that runs from the forty-second milestone on the Holyhead road to Afon-ystymiau. The synclinal curve on the slope south-east of the top of Moel Siabod, shown in the diagram, is quite certain, and though there is no direct connexion on the surface of the ground between the greenstone marked *g* and that marked *g′*, it seems not unlikely that these and the other patches that break out on the slope of the hill are all connected at no great depth beneath the surface. Like others of their class, having been injected before the contortion of the country took place, they are necessarily affected by its curves.

CHAPTER XVIII.

The Bala Beds and interbedded Igneous Rocks between Bettws-y-Coed, Moel Siabod, Llyn-Ogwen, and Conway, and the Intrusive Masses between Conway and Y-Foel-fras.

General Description.—Having established the stratigraphical horizon of the rocks of the valley of Dolwyddelan and Moel Siabod, it becomes comparatively easy to show their relations to those of the mountain region to the north and north-west, as soon as the interbedded character of the greater part of the igneous series of the Snowdonian mountains is recognised.

North of Moel Siabod the Bala beds assume a markedly different character from that which they possess between Dinas-Mowddwy and Dolwyddelan, for they become mixed with a much greater number of beds of felstones and volcanic ashes, which range northward to Conway, and from thence south-west along the higher Caernarvonshire mountains. Y-Foel-frâs, Carnedd-Llewelyn, Carnedd-Dafydd, Y-Glyder-fach, Y-Glyder-fawr, Snowdon, and Moel-Hebog, are the chief mountains in this the highest, wildest, and grandest part of North Wales; and these, like the ranges of Cader Idris, the Arans, and Moelwyn, consist in a great degree of true volcanic products, some of which are interbedded, and some of the intrusive masses may be the deep-seated centres of volcanic eruptions. It has been already stated that these volcanic rocks belong to two sections of the Lower Silurian period, for the felstone porphyries and felspathic ashes, and perhaps even the intrusive greenstones of Merionethshire, were formed during the deposition of the Arenig strata, while the same kinds of thick-bedded traps and ashes on Snowdon and the surrounding mountains are high in the Bala or Caradoc series. In both cases they form the highest mountains in Wales, not from upheavals caused by the *intrusion* of igneous masses in special areas, nor yet because any relics of the lips of lofty craters as originally formed by accretions of lavas and ashes still exist, but simply from the circumstance that long after their formation, and after the volcanos had become extinct, having been already much denuded and lying deep below thousands of feet of newer strata, the whole mass of the Lower Silurian and Cambrian rocks of the area were at length disturbed together, and rolled into great curving lines; and the hard felspathic igneous masses now rise so high, because they better withstood degradation than some of the areas occupied by the softer slaty rocks with which they are interbedded. It is worthy of remark that the ranges formed of the lower porphyries, &c., of Cader Idris, Aran Mowddwy, Arenig, and Moelwyn, lie in the Arenig beds, midway up in the strata of the great Merionethshire anticlinal, while the peaks of the newer series of igneous rocks that form the range of Moel-Hebog, Snowdon, Glyder-fawr, Carnedd-Llewelyn, and other mountains in Caernarvonshire, actually lie in the middle of a

basin (Section No. 3, Pl. 28). The whole form but minor parts of an old mountain system now broken into fragments, of which Wales is only a fragment, the history of which this is not the place to describe.

The circumstances attending the formation of the two volcanic series seem to have been of this kind. At the beginning of that minor epoch, when the Arenig beds were being deposited in this area, volcanic eruptions took place beneath the sea, and as the lavas and ashes accumulated, it is probable that a volcanic island or volcanic islands were formed, from the growing craters of which, gradually rising in height (while the islands increased in bulk), other eruptions took place, and the larger stones, mingled with finer ashes, were, on the shores of these islands, waterworn and rounded by the action of the surf. When this period of volcanic activity ceased, long-continued denudations, both subærial and marine, washed away the elevated cones, more or less shaving them across, *and reducing them to plains of marine denudation.* During and after this process the whole region in the course of time got deeply buried under strata of the Caradoc or Bala epoch, which east of Arenig the Arans and Cader Idris attain a thickness of from 6,000 to 7,000 feet. Then newer volcanic eruptions took place in neighbouring areas, and the upper series of volcanic rocks were formed, of which Snowdon forms a part, in their turn to be buried under that higher part of the Bala or Caradoc series that succeeded the deposition of the Bala limestone.

The Mountains North of Capel Curig.

I shall now describe the rocks of part of Caernarvonshire between Bettws-y-Coed, Moel-Siabod, Llyn-Ogwen, and Conwy.

At first sight it requires an effort to believe that most of these rocks are the actual equivalents of the slender band of Bala limestone, near Bala, and of the slates and insignificant ashy bands that underlie it. Nevertheless, alike physically and palæontologically, the evidence is clear; and only in one or two spots on the banks of the Conwy do any of the rocks of that large area rise a little higher than the parallel of the Bala limestone; while by far the larger part is either on or a little below that parallel. It is not, indeed, till we reach the neighbourhood of the village of Llanberis and the middle of Nant Francon, far below the falls of the Ogwen, that we get as low as the horizon of the Arans and Arenigs, and find that their lavas and ashes are utterly unrepresented among the slaty rocks of Caernarvonshire.

Moel Siabod and Y-Tryfan.—Descending on the northern side of Moel Siabod, the green slopes consist, first, of slaty beds, and, lower down in the cliffy region, of largely bedded grits (4, Fig. 33) that overlook the valley of Nant-y-gwyrd. They are the equivalents of the Bala beds between Dolwyddelan and Moel-farllwyd (Fig. 31), and contain *Stenopora fibrosa, Asaphus Powisii, Orthis elegantula, Murchisonia simplex, Orthocerata,* and other Bala fossils. In the midst of the grits there appears a bed of felspathic trap, which does not rise to the surface on the south side of the synclinal curve of Dolwyddelan. Its position is represented in the following diagram, which may be considered a continuation of Fig. 31.

The felstone (No 3) rolls over in an anticlinal axis, as drawn on the maps* and sections, and curves round in an oval form immediately south-west of Capel Curig, including in its sweep the lakes of Llynjau Mymbyr. The rocks in front of the hotel form part of it. On the north side of the road it splits into three bands, and passing under the slates and grits of Cefn-y-Capel, it again rises in three masses in the cliffs of Gallt-y-gogo, or Gallt-yr-ogof, two miles west of Capel Curig (No. 3). These are rolled over in a bold anticlinal curve, about two miles wide, and form the sharp peak of Y-Tryfan, where, on the eastern cliff, a good eye can easily detect, from the valley below, three beds of felspathic porphyry interstratified with slate, dipping west at an angle of about 60°. Two great upright stones, the result of subærial denudation on the jointed rock, stand on the top of the mountain. The eastern cliff, which is not easily accessible, is bare, and largely jointed, and the west slope, besides being steep, is cumbered with immense masses of stone, which, piled on each other, render the ascent somewhat difficult, except to accustomed mountaineers. Fossiliferous grits (No. 2) underlie this, and in the midst of them there is a bed of felspathic porphyry, marked No. 1. Y-Glyder-fach is partly formed by a continuation of the felstones of Y-Tryfan, as shown on the map. It is peculiarly rough and craggy, and the weary barren slopes that sweep round above Pen-y-gwryd are cumbered with huge blocks of felspathic porphyry, tufted with moss and heath. There the trap and overlying grits, partly ashy and brecciated, dip W.S.W. and south-east, curving round in an oval form to join the same rocks on Gallt-y-gogo, and the whole lie about 400 feet below the igneous rocks of Snowdon, afterwards to be described (pp. 138 and 141).

From Gallt-y-gogo the same felspathic band strikes north about eight miles, passing through the lakes of Ffynnon Llugwy, Melynllyn, and Llyn-dulyn. Beyond Pant-glas, four and a half miles E.S.E. of Aber, it is thrown, along with other rocks, to the north-west in a succession of blocks of country, by nine faults that lie between the Llanbedr and Aber fault and the neighbourhood of Conway. Here also a great lower mass of felstone porphyry extends between Conway mountain and the carns of Y-Drosgl north of Y-Foel-frâs. (*See* 1-inch Maps.)

If on the opposite side of the anticlinal bend we trace the rocks of Y-Tryfan northward, we shall find that the two higher beds of its felstones strike through Ffynnon-y-lloer to the top of Carnedd Dafydd, where they curve round to the south with an eastern dip, and entirely thin away on the rugged slope of Craig-yr-hysfa above Nant Francon. In the midst of the anticlinal (which may be likened to a dome) there is a lower oval-shaped line of felspathic rock with a quaquaversal dip. Grits underlie and slates overlie it. Amid these, on the north, is a short bed of felstone passing into the hill in the form of the letter V reversed. Both of these, passing beneath the grits west of Ffynnon Llugwy, rise again along the east side of Carnedd Llewelyn. The higher strikes north for about three miles; the lower is cut off by the greenstone of Cefn-yr-Arryg. In the opposite direction, partly broken by faults, they curve along the north side of Carnedd Dafydd, then striking southwards through Craig-yr-hysfa they reach Nant Francon, less than half a mile below the bridge. It will be observed that this curve forms the northern spoon-shaped end of a synclinal curve, which bends upwards to the east and west between Cwm-Tryfan and Nant Francon,† and it is worthy of remark that none of these minor beds, and only a trifling representative of the immensely thick interbedded porphyries of Y-Tryfan and Y-Glyder-fach (diagram 33) come up with the western rise of the synclinal curve on the Llanberis side of Nant Francon, so that about 1,600 feet of these lavas thin away in little more than a mile between the east end of Llyn Ogwen and the banks of the river a little below the Falls.

Fossiliferous grits and slates both overlie and underlie the felstones of Y-Tryfan and Gallt-y-gogo (Figs. 33 and 34) throughout all their range from the upper part of the Pass of Llanberis to the neighbourhood of Conway. From the Pass the higher grits and slates regularly accompany the felstone of

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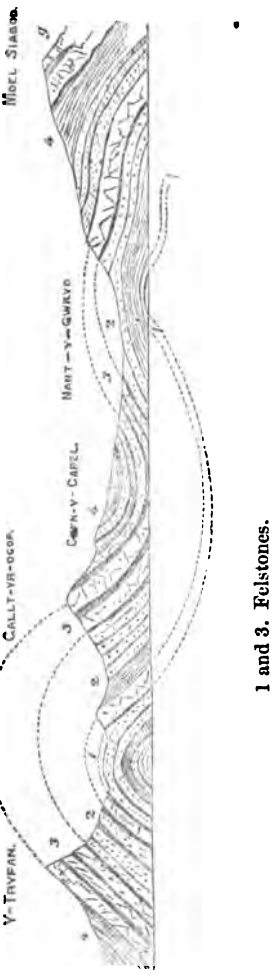
* 78 S.E. and 75 N.E.

† The continuation of this synclinal line forms the basin in which Snowdon lies, *see* p. 141.

Fig. 33.

SECTION ACROSS THE BALA BEDS FROM MOEL SIABOD TO Y-TRYFAN, LLYN OGWEN.



1 and 3. Felstones.
2. Grits
4. Slates and grits } Fossiliferous Bala beds.
g. Greenstone.

Gallt-y-Gogo in its northern strike. On Cefn-y-Capel these are principally arenaceous slates, except one marked bed of grit near the base. North of Cwm-tal-y-braich they gradually become more sandy,* and on the hills west and north of Clogwyn, near Llyn Eigiau, they resolve themselves into several distinct bands of slate and grit, containing numerous casts of ordinary Bala fossils. West of Y-Tryfan, on either side of Llyn Ogwen, the same beds are also fossiliferous. The lower gritty beds of the anticlinal curve are well exposed, sweeping round the top of the valleys in magnificent terraces, underneath the felstones of Gallt-y-gogo, Y-glyder-fach, and Y-Tryfan. At the very base, close by the old road between the farms of Wern-go-isaf and Wern-go-uchaf, the flattened centre of the anticlinal may be seen rolling over to the east and west (Fig. 33).

The following fossils were collected from these strata by Mr. Salter:—*Favosites fibrosa, Cornulites serpularius, Rhynchonella serrata* (*Llandoveryana*), a small *Lingula*, and *Modiolopsis*.

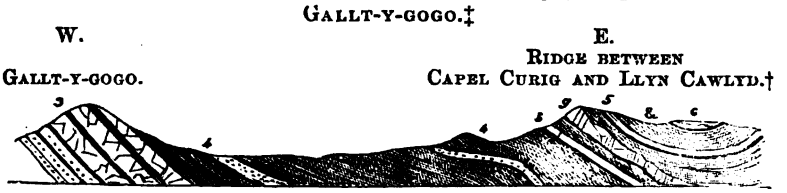
Capel Curig.—East of the long lines of felstones, slates, and sandstones that strike from Gallt-y-gogo towards Conway, there lies between Llyn Cawlyd, Llyn Eigiau, and the river Conwy, a slaty country, with greenstones and interbedded felspathic rocks, the relation of which to the other rocks I shall now briefly describe.

North of the Holyhead road between Bettws-y-Coed and Capel Curig there is a broken rocky escarpment, formed of interstratifications of felspathic rocks and slates. With minor undulations the general strike of these is east and west as far as the hills that overlook Capel Curig, where they suddenly bend round and strike north to Llyn Cawlyd† in a bold picturesque ridge. Between Bettws-y-Coed and Llanbedr on the left bank of the Conwy there is another high escarpment formed (in general terms) of the same set of rocks. The intervening space between the Conwy and Llyn Cawlyd thus consists of a kind of undulating tableland intersected by valleys and lakes, rarely visited by the tourist, some of which are mere reedy pools, and others, such as Llyn Geirionydd and Llyn Crafnant, are of larger size, and possess a pastoral beauty almost peculiar to themselves in Wales. Above the porphyry that encircles Llyniau-Mymbyr the ascending section north-east of Capel Curig is as follows:—First, certain slaty beds that contain a short thick band of conglomeratic ash, which forms a little rocky hill close to the road nearly opposite the turnpike gate, and strikes northwards about half a mile, when the ash disappears. Eastward of this as far as Clogwyn-manod there are four or five beds of interbedded felspathic ashes, the highest of which forms a little outlier, and consists of felspathic matter mingled with the ordinary mud of the period.

The section between Gallt-y-gogo and the rocks of this ridge is as follows, Gallt-y-gogo itself being formed of the equivalent of the felstone rocks that encircle the lakes of Capel Curig.

Fig. 34.

SECTION BETWEEN THE NEIGHBOURHOOD OF CAPEL CURIG AND GALLT-Y-GOGO.‡



3. Three beds of felspathic porphyry overlying fossiliferous grits, and interstratified with slate.
4. Slates and grits of Cefn-y-Capel, fossiliferous.
g. Greenstone intruded between the beds of slate, which are changed into porcelanite both above and below.
5. Bedded felspathic traps, and
6. Ashes interstratified with slates.

* Two and a half miles west of Capel Curig.
† Mis-spelt Cwlyd on the map.
‡ Or Gallt-yr-ogof.

Further north the equivalent rocks on the slope above Llyn Cawlyd present a similar arrangement, and the same may be said of the rocks between Llyn Bodgynwydd, Llyn Goddion-duon, and the Holyhead road, about half-way towards Bettws-y-Coed. By inspecting the larger map (78 S.E.) it will be seen that some of the beds of felspathic rock in this district thin out in lenticular forms, being not more than half a mile in length.

The topmost igneous bed by Llyn Goddion-duon immediately above the Holyhead road is the equivalent of the outlier of Clogwyn Manod. Its character is peculiar, consisting of a dark blue or black slaty base containing numerous scattered crystals of yellow felspar, which gradually increase in quantity as we follow the bed, till at last the slaty impurities entirely disappear, and north of Llyn Bodgynwydd it becomes an ordinary felspathic ash. East and north of this lake it widens, capping the whole summit of Pen-uchaf-y-gwaith, from whence striking northwards, it is lost under the alluvium of the Conwy at Ysgubor-gerig about half a mile south of Trefriw. An outlier of the same rocks skirts the woods of Llyn-y-parc on the west, and a north and south fault, that strikes along Nant-Gwydir and the lake, throws down a higher part of the Bala beds against the ash and interstratified slates.

Fig. 35.

6. Ash and slate.
7. Bala beds above the equivalents of the Bala limestone.

In many parts of its range south of Trefriw the ash is highly porphyritic, distinct, crystals of felspar imperfect or broken being embedded in a base which weathers brown at the surface. At Cwm-lanerch, about two and a half miles south of Llanrwst, these higher strata are full of *Trinucleus concentricus*, *Leptæna sericea*, and other common Bala fossils.

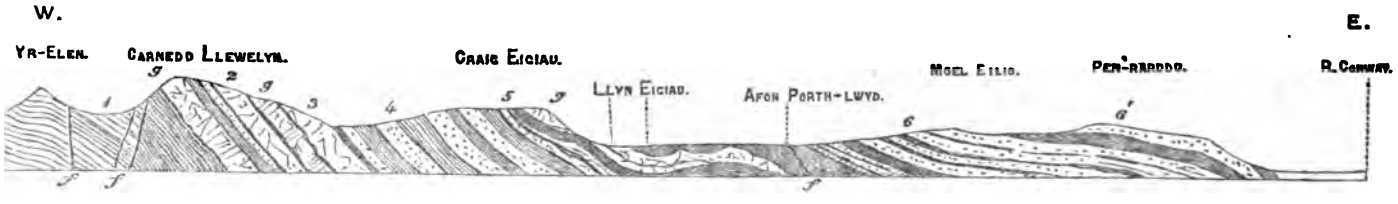
On the opposite side of the synclinal, west of Llanrhwchwyn, the same ash bed skirts Llyn Geirionydd, striking north about a mile beyond Bedd Taliesin, and from thence, with many branchings, it curves round and thins out about a quarter of a mile north-east of the efflux of Llyn Cawlyd. The whole country is full of injected greenstones, which, without narrow inspection, might be supposed to be interbedded in the same manner as the felstones. This is especially the case on the hill that overhangs Llyn Cawlyd, where bands of slate, felstone ashes, and greenstone alternate with great regularity; but on close inspection it is found that these greenstones here and there branch in dyke-like fashion into various horizons, and also that whereas the slates are quite unchanged when only associated with felspathic ashes, in contact with the greenstones they assume a porcelanic texture both above and below the injected rock. These porcelanites weather white, like the felspathic rocks, and I found it no easy matter to separate the two while mapping the country between Pen-uchaf-y-Gwaith, Llyn Cawlyd, and Capel Curig. The same may be said of the country east of Llyn Eigiau, mapped by Mr. Aveline, and these facts, added to the contortion of the beds and the incessant appearance and disappearance of felspathic interstratifications, rendered this country peculiarly tedious and difficult to unravel.

Carnedd Llewelyn, the Vale of Conwy, &c.—North of Trefriw the same bed of volcanic ashes that dips under the alluvium of Ysgubor-gerig, reappears on the left bank of the Conwy between the fourth milestone and Llanbedr, and forms all the high ground for about a mile in width from Pen-'r-arddu and Gallt-y-rhiw to Pen-y-gaer and Llanbedr, where it is cut off by two faults, downthrows, on the south-west and south-east.

The whole in places becomes a porphyritic conglomerate or breccia, fragments of felspathic lava being embedded in a porphyritic felspathic base. Some of its beds are finer grained and of a dark hue, decomposing brown at the surface, while others are of a light grey tint, when the rock is freshly

Fig. 36.

SECTION ACROSS THE BALA BEDS FROM YR-ELEN TO THE RIVER CONWY, BETWEEN LLANBEDR AND TREFRHIW.



1. Slaty beds of the Bala series underneath the parallel of the Bala limestone, faulted, but on the whole dipping east.
g. Intrusive masses of greenstone forming a large part of Carnedd Llewelyn, and of the cliff above Llyn-Eigiau.
2 and 3. Beds of interbedded felspathic porphyry, the upper bed of which is the equivalent of the felstones of Gallt-y-gogo or Gallt-yr-ogof (Figs. 34 and 33). They are interstratified with grits containing *Orthis calligramma* and other Bala fossils.
4. Fossiliferous grits and slates, equivalents of the rocks of Cefn-y-Capel, and the north-west side of Moel Siabod (Fig. 33).
5. A thin bed of felspathic ash.
6 and 6′. Slate overlaid by and interstratified with beds of felspathic ashes.
f. Faults.

The ashes No. 6 and 6′ are the general equivalents of those above the felstones of Dolwyddelan, and therefore the representatives of the Bala limestone and of the top of Snowdon. The slates of Llan'rhwchwyn and Cefn Careadwydd overlie it, and form one of the highest portions of the Bala beds in this part of North Wales.

fractured. At its southern end it is probably faulted, and abuts against a solid bed of pinkish-white felspathic porphyry near Dol-garrog.

About three miles, by the map, east of the Penrhyn slate quarries there is a steep conical slaty hill called Yr-Elen. A section drawn east from this hill through Llyn Eigiau, and over Pen'r-arddu to the river Conwy, gives the same general arrangement of beds as that immediately east and north of Capel Curig, Fig. 36.

Opposite Llanrwst two faults coalesce and pass up the vale of Conwy under the alluvium to Llanbedr, near which the fault branches in several directions, one branch passing towards Conway by Y-Ro, another towards Penmaen Mawr, and a third to Aber. A fourth fault joins it near Llanbedr, and probably striking south-west by Yr-Elen, Llanberis, and Llanfihangel-'y-pennant, seems to be lost in Cardigan Bay near Criccieth. It cuts across the interbedded felspathic trap of Carnedd Llewellyn (No. 2, 3, Fig. 36) between Y-Foel-frâs and Llyn Dulyn, throwing them slightly down in the south. Beyond this dislocation these rocks still strike to the northwards, dipping easterly at angles from 50° to 60°. At the upper part of Afon-Ro they are affected by the Aber and Llanbedr fault, which is there a downthrow, on the north; and between this point and Conway the course of the same bed of felspathic porphyry and overlying fossiliferous grits is disturbed by ten faults, each in succession throwing them a little further to the north-west.

The grits are overlaid also by beds of felspathic ashes accompanied by numerous bands of greenstones, intruded more or less in the line of strike. The whole, as near as may be, form the equivalents of similar rocks that, south of Llanbedr, lie between the Conwy and the east slope of Carnedd Llewelyn, and Gallt-y-gogo two miles west of Capel Curig.

Conway.—North of Conway, interstratified with slates, these rocks rest on the felspathic mass of Conway mountain, dipping south at angles of about 60°. In the estuary they are cut off by a fault which is a downthrow on the east, and on the west they are thrown by another dislocation against the trap of Penmaen-bach and Dinas. Another fault cuts off the grits on the south, throwing down higher beds against them, which are sometimes calcareous, and contain many of the ordinary Bala limestone fossils, usually in a fragmentary state. Conway Castle is built on one of these beds, dipping south at an angle of 60°, and the same grits occur on the opposite bank of the estuary, near the trap of Diganwy and east of Bryn-y-Gosol. It is there of a dark bluish grey hue, calcareous, and slightly conglomeratic, containing numerous rings of *Encrinites* and casts of *Orthis*.

These rocks lie amid black slates, and are much contorted and altogether bounded by faults. They are probably equivalent to some of the higher strata between Trefriw and Llyn Geirionydd and of the Bala limestone. The whole are much obscured by drift; and north of Conway they are overlapped by the Carboniferous limestone which on Great Ormes Head creeps across the strike, and passing underneath the sea to Anglesea, at the entrance of the Menai Straits, north of Beaumaris, it lies on Arenig strata much beneath the stratigraphical horizon of the rocks near Conway.

Penmaen-mawr, &c.—West and south-west of Conway there are three great masses of felspathic porphyry, forming the shingly heights of Penmaen-bach, Penmaen-mawr, and Dinas. The rock is of a bluish grey tint, and chiefly consists of small felspar crystals, occasionally associated with a very small proportion of hornblende. Where visible, the black Silurian slates in contact with them are much altered; and though the form of the ground seems to indicate that the rock of Penmaen-mawr rests upon the slate with a northern dip, yet the massive and crystalline character of the rocks of the three heights named above, and their boss-like forms, seems to show that they are intrusive masses, and not interbedded felspathic lava-flows.

Between Penmaen-bach and Y-Drosgl, about 3 miles east of Aber, a broad thick sheet of felspathic porphyry overlies the slate in which these instrusive masses lie. Occupying a given horizon, and being both underlaid and overlaid by continuous bands of slate, with which it dips east and south-east, there can be little doubt of its true interbedded character. On the south it is cut off by the Aber and Llanbedr fault, and abuts on the massive porphyry of Y-Foel-frâs, with which it is not unlikely that it may have been originally

Fig. 37.

SECTION ACROSS THE BALA BEDS FROM DOLWYDDELAN TO THE ROCKS NORTH-WEST OF BETTWS-Y-COED.

No. 6, calcareous ash and slaty beds of Dolwyddelan on the south, part of which is the equivalent of the Bala limestone. 5. Felstone. 4. Fossiliferous slates and gritty Bala beds underlying the Dolwyddelan felstone, and equivalent to the grits and slates of Moel Siabod, marked No. 4 in Figs. 33 and 34. 3. Felspathic porphyry (the equivalent of No. 3 of Figs. 33, 34, 36). It rises from beneath No. 4, and is exposed by denudation in Glyn Lledr, where it rolls over in an anticlinal curve on either side of the valley, so that the slates No. 4, on the river Llugwy are again capped by felspathic ash and slate, No. 5′ and 6′, between the river and Pen-uchaf-y-gwaith. These are evidently by position the equivalents of the rocks Nos. 5 and 6 in the valley of Dolwyddelan. and therefore in part represent the Bala limestone.

connected—the great boss forming an underground volcanic centre, and the interbedded rock being perhaps one of the lava beds that proceeded from it. Of the intrusive nature of the porphyry of Y-Foel-frâs there can be no doubt, for wherever slates are seen in contact with its unfaulted boundary they are highly altered. At the cascade above Aber, this porphyry forms the rock over which the water falls. Close to this point the strata have been changed to a kind of quartzite, and in other places near they have been baked into porcellanite. Receding from the trap, they rapidly pass into common slate. The stratification at this point is obscure, but it seems probable that bedding and cleavage coincide, being nearly vertical, or dipping sometimes towards and sometimes from the porphyry at angles of from 80° to 85°. The igneous rock rises like a great wall on its north-west boundary. At its edges it is often fine-grained and weathers yellow, and it appears not unlikely that this may be due to the circumstance that some of the melted mass may actually consist of fused Silurian strata; for highly altered slates are often almost indistinguishable, even when fractured, from compact felstones. Beyond this yellow band the rock assumes something of the character of a greenstone, crystals of felspar and hornblende being intermingled, although the former generally much predominate. Further in still, the great mass may be described as a felspar porphyry, numerous well defined crystals of felspar being embedded in a felspathic base sparingly associated with hornblende. In several places, however, it becomes a true hornblendic greenstone, and all the varieties pass gradually into each other.

Equivalents of the Bala Limestone, &c.

I have stated that the beds west of the Denbighshire sandstone between Capel-Curig, Bettws-y-Coed, and Conway, are the true equivalents of the beds immediately associated with the Bala limestone, and that some of them represent that limestone itself. The absolute proof is as follows:—

It has been shown (pp. 126 to 129) that the calcareous ash of the valley of Dolwyddelan is the equivalent of the Bala limestone, and its position with reference to the fossiliferous grits and interbedded felspathic trap around Llyniau-Mymbyr near Capel-Curig is explained in Diagrams Nos. 31 and 32.* But the Llyniau-Mymbyr porphyry being equivalent to that of Gallt-y-gogo, and the great bed that runs from thence towards Conway, it is evident from a consideration of Diagrams Nos. 33 and 34 that the ashes and slates north of the road between Capel-Curig and Bettws-y-Coed bear the same relation to it that the Dolwyddelan calcareous and felspathic ash does to the trap of Llyniau-Mymbyr. Further, if we construct a section from Dolwyddelan north-east to Glyn-Lledr, and from thence north to Pen-uchaf-y-gwaith, a mile south of Llanrhwchwyn, near Llanrwst, the arrangement of the rocks is as shown in Fig. 37.

A glance at the map shows that the same part of the Bala beds is continuous from thence along the left bank of the Conwy to the mouth of that river, as already described; and at Conway itself, in the very same position with regard to the traps and grits of Conway mountain, there occurs the calcareous fossiliferous grit, which lies in the place of the Bala Limestone, and I believe is its absolute equivalent.

* Also the Sheet of Horizontal Sections, Sheet 31, line 3.

CHAPTER XIX.

The Snowdon Area and Moel Hebog.

General Description.—The felstones and ashes of the Snowdon area form the most important members of the igneous series of Caernarvonshire. Indeed, the grandest part of this country, both as regards the scale of the igneous phenomena, and the consequent magnificence of its scenery, is owing to the hard and soft layers concentrically interbedded in a great trough shown in the easterly dips of the slates, grits, and traps on the flanks of Moel-Hebog, Snowdon, Y-Garn, and Carnedd-Dafydd; while the opposite inclination of the rocks on the summit of Y-Glyder-fawr, Y-Tryfan, and part of Carnedd-Dafydd, forms the eastern side of the basin. This trough contains within itself several smaller undulations, the highest of its beds being on the parallel of the Bala limestone, and the whole area forms an inner part of a much greater synclinal curve shown in the general south-easterly dip of the Cambrian and Lower Silurian strata north-west of Carnedd-Llewelyn, Snowdon, and Moel-Hebog, and in the average north-westerly inclination of the strata of the Moelwyn range and the Cambrian beds below. Between Llyn-Ogwen and the Manods, indeed, the simple form of the basin is in a manner lost in the subsidiary undulations of Dolwyddelan, Nant-y-Gwyrd, and Cwm-Tryfan, but on a large scale it exists. The whole country may be likened to a set of crumpled sheets of paper, to the folds of which a general but irregular direction has been given, and in which some of the larger trough-shaped bends are interfered with, and die out, in consequence of the appearance of other anticlinal and synclinal curves.

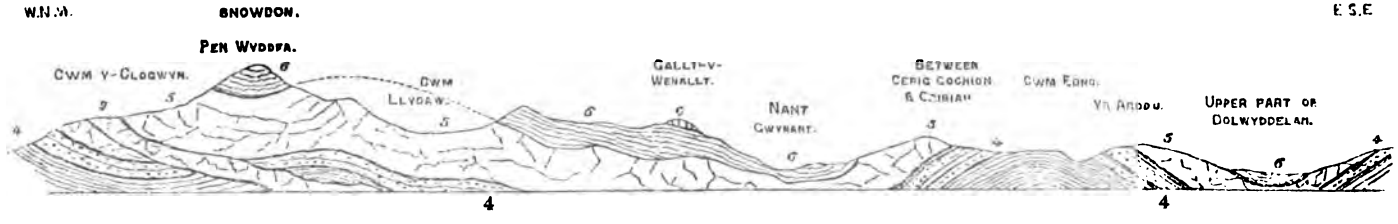
By carefully considering these curves, the identity of the Snowdon rocks with those of Dolwyddelan is proved, thus directly linking both to the horizon of the Bala limestone. The following is the proof:—

Snowdon and Dolwyddelan.—It has been already stated* that fossiliferous grits rise on the south and north from under the felstones of Dolwyddelan. At the west end of the valley the same strata rise from under the porphyry of Yr-Arddu, and rolling over to the west plunge at angles of from 10° to 25° beneath the felspathic porphyry of Cerig-Cochion and Cribiau, east of Llyn-Gwynant. These grits and overlying felspathic rocks are therefore equivalents. But a glance at the map and the following diagram, No. 38, will show that the felstones of Cerrig-Cochion and Cribiau form part of that mass which circles round and constitutes a great proportion of the rocks of Snowdon, and that in the Snowdon district it is overlaid by calcareous and felspathic ashes between Llyn-y-Ddinas, Llyn Gwynant, and Llyn-Llydaw. These ashes therefore stratigraphically bear the same relation to the Snowdon and Cerrig-Cochion felstones that the ashes of Dolwyddelan do to the underlying porphyry there, and the rocks

* Pp. 126 to 128.

Fig. 38.

Section from Snowdon to the Valley of Dolwyddelan.



4. Grits, fossiliferous, overlying slaty beds.
5. Felspathic porphyry (lava beds).
6. Volcanic ashes, sometimes calcareous and fossiliferous = Bala limestone.
c. Columnar felspathic trap of Gallt-y-Wenallt.
g. Greenstone (intrusive).

of Dolwyddelan form therefore an outlier of the larger mass of Snowdon and Nant-Gwynant. A line of section drawn from the Dolwyddelan basin across Llyn-Gwynant, and from thence to the top of Snowdon, gives an arrangement of the rocks as shown in Fig. 38.

On the south-east the ash No. 6 consists of "a greyish green "or green and white spotted rock, very calcareous, and decom- "posing into a soft brown earthy substance similar to an ashy bed "that in places accompanies the Bala limestone;"* or, not unlike the limestone itself, where it is occasionally somewhat mixed with volcanic substances. At the west end of the valley it lies on the mass of felspathic porphyry (5), which contains well-formed separate crystals of white felspar, and forms the hill of Yr-Arddu. Beds of fossiliferous greenish grey grits and slates rise (4) from under it, which, rolling over to the north-west again, dip under the slaggy-looking felspathic trap of Cerig-Cochion (5), the weathered surfaces of which show beautifully contorted lines of the kind described at p. 153. West of Cerig-Cochion and Cribiau† the ash (6) dips downwards into the valley of Nant-Gwynant by the lake, and rising on the flank of Snowdon it rolls across Llyn Llydaw in a denuded anticlinal curve, and is caught again on the peak of Snowdon above the felspathic porphyry (5). On Gallt-y-wenallt an upper felstone *c* (which will be subsequently described) just tips the ashy rocks, and both ash and lower porphyry gradually thicken between Dolwyddelan and Snowdon. Beneath the porphyry at Cwm-y-Clogwyn coarse grey grits (4) rise to the surface, the general equivalents of those between Yr-Arddu and Cerig-Cochion. A line of greenstone *g* pierces the rocks in Cwm-y-Clogwyn.

The above diagram clearly shows that the ashes, porphyry, and grits of Dolwyddelan and Snowdon are the same, and the calcareous ash of Dolwyddelan being the equivalent of the Bala limestone,‡ the ashes of Snowdon also belong to the same geological horizon, while the rocks both of Snowdon and Dolwyddelan collectively are the general equivalents of the complicated interstratifications of slates and igneous rocks that run from Capel-Curig and Bettws-y-Coed to Conway.§

Snowdon and Nant Gwynant.—Before describing the underlying rocks in detail, I shall give an account of the general lithological characters of the ashes on and around Snowdon. As a whole, they are well stratified, and in many respects resemble those that underlie the older prophyries of Aran Mowddwy and Cader Idris.

It should be understood that it is not implied that from top to bottom they are formed of good typical volcanic ash or tuffa. On Snowdon they are partly less so than the more ancient ashes of Cader Idris and Aran Mowddwy. Sometimes they seem pure, and sometimes intermixed with every possible percentage of other sediments, muddy, sandy, and calcareous. Sometimes they are scoriaceous, rough, and stony, and sometimes as smooth and compact as the most close-grained felspathic trap, having been formed by the consolidation of felspathic dust, blown out from the same volcanic sources that yielded the

* A. R. Selwyn, M.S.
† About 2 miles east of Llyn Gwynant.
‡ *See* p. 128.
§ *See* pp. 134 to 137.

felspathic lavas. In other cases crystals of felspar often broken are embedded in a felspathic base, forming a stratified porphyry. Where ordinary sedimentary matter predominates they are apt to be fossiliferous, and contain Bala species. To separate each variety according to its kind would perhaps be impossible on any scale of map, for not only are they interstratified in every possible variety, but they also merge into each other in the strike in the most capricious manner. It was as much as could be done on a one-inch scale to indicate the whole mass in the manner shown, on which the Lower Silurian base of colour serves to mark its stratified origin, and the dottings of red, yellow, and blue represent its ashy, sandy, and calcareous intermixtures. Over considerable areas the mode of colouring might with equal propriety be reversed, and adopting red for a base, dots of purple, blue, and yellow might be placed on it to indicate other substances mingled with the purer felspathic ash; but, on the whole, the ordinary sediment predominating, the Silurian colour has been chosen as a base.

Between Tremadoc and Llyn Ogwen the ashes occur in four distinct patches, all formed of equivalent strata. One of these lies between Beddgelert and Llyn-y-Ddinas on the southern side of the river. On the east it is partly faulted against the Bala beds that underlie the felstone on which it rests. Another, lying partly in Nant-Gwynant, occupies an irregularly triangular trough, the narrower end of which occupies the hills that approach Llyn-y-Ddinas, while the broad end stretches east and west between Cribiau and Llyn Llydaw on the eastern flanks of Snowdon (Fig. 38). A third lies on the side of Moel Hebog; and the fourth forms the peak of Snowdon (Figs. 38 and 39), and stretches east along Crib-goch and north to Twll-du above Llyn Idwal.

The rocks of Nant-Gwynant and Beddgelert possess forms of such extreme irregularity that I must refer to the map for their outline. They are contorted and faulted, some of the fractures being copper lodes, which have not generally been worked to much profit. At Llyn Gwynant the ashy beds and undulating felspathic trap dip north-west, and then rise in an opposite direction. The ash is well seen on the road for about a mile and a half north-east of the lake. Its bottom beds are there shaley, and contain a nodular felspathic band, above which are greenish, grey, and brown calcareous and sandy beds, on which there rests a brown calcareous breccia and conglomerate.

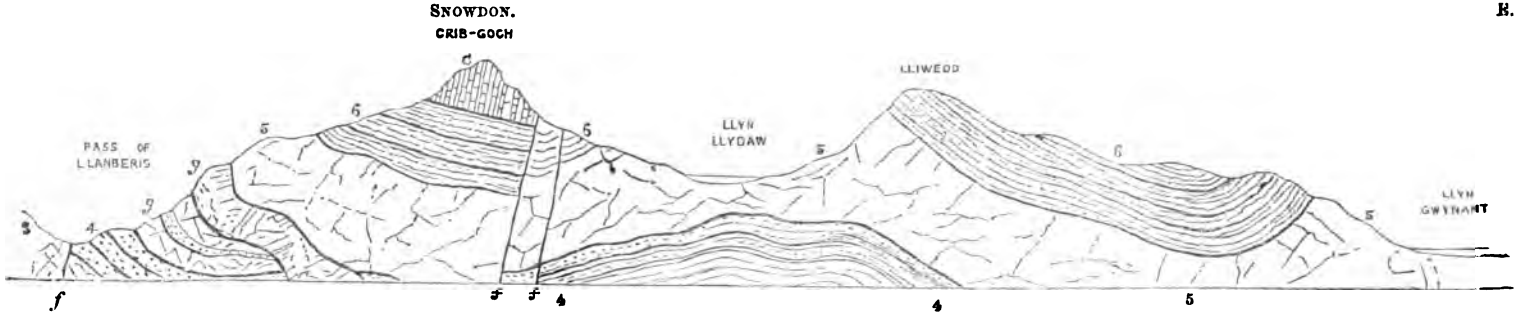
The following typical descriptions of the same rocks on the opposite side of the valley are partly derived from the note books of Mr. Selwyn. On the west shore of Llyn Gwynant "the beds dip north-west 45° to 50°, and are "formed of soft greenish calcareous ash, which decomposes into a dark brown "earthy rock. On the map, 260 yards north of the Y of Gwynant, they con-"sist of a hard grey calcareous rock, which weathers like the *Bala limestone*" in rough irregular cavernous lines. "This again becomes a soft gritty ash, "with nodules and angular fragments of good crystalline limestone (Fig. 38). "These beds are somewhat similar to some of those near the top of Snowdon. "A little further westward, on Gallt-y-wenallt, there is a felspathic breccia and "vesicular ash, the vesicles being filled with carbonate of lime." This is the same breccia that we find on the east side of Nant-Gwynant, but between Llyn Gwynant and Gallt-y-wenallt it has become much harder and more felspathic, large blocks of felspathic porphyry being imbedded in a hard felspathic base. Between Llyn Gwynant and Llyn Llydaw the beds lie in an inclined synclinal curve in the manner shown in the diagram, Fig. 39, where No. 6 represents the beds of brecciated scoriaceous ashes, and 5 the underlying slaggy-looking felspathic porphyry. The ashes and felspathic trap then roll across the valley to Crib-goch (above the Pass of Llanberis), where the ash is capped by several outlying patches of columnar felstone c of the section Fig. 40.

The finest section of the ashes anywhere in Caernarvonshire is seen in the dark and lofty cliffs of Lliwedd that overhang Llyn Llydaw, Fig. 40. There they consist of greenish grey calcareous beds, mingled with occasional felspathic breccias and conglomerates. They are sometimes fossiliferous, and the precise equivalents of the ashy rocks that form the peak of Snowdon* (Fig. 38) and part of the serrated ridge of Crib-goch. On the crest of Lliwedd, two

* Pl. 28, No. 3, and 6-inch section, Sheet 28, line 2.

Fig. 39.

SECTION FROM THE PASS OF LLANBERIS OVER CRIB-GOCH AND LLIWEDD TO LLYN GWYNANT.



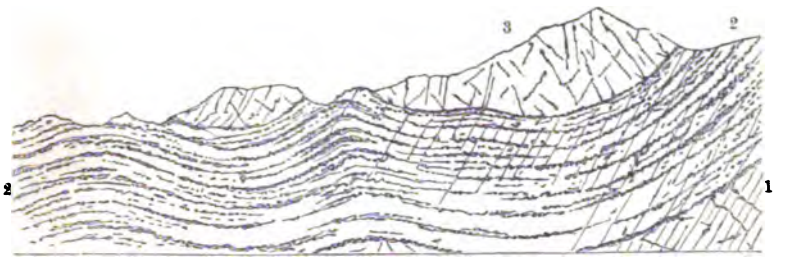
3. Felspathic porphyries of Esgair-felen, dipping south-westerly.
4. Grit beds near Pont-y-gromlech.
5. Felspathic porphyries of Snowdon, Llyn Llydaw, and Llyn Gwynant.
6. Calcareo-felspathic ashes of Cwm-glas and Lliwedd.
c. Columnar felspathic porphyry of Crib-goch. Outlier.
g. Greenstones.
f. Faults.

small isolated patches of compact blue felstone, equivalent to those of Crib-goch (Fig. 39), rest on the beds of ash in the manner shown in the accompanying diagram by Mr. Selwyn.

Fig. 40.

PART OF THE CREST OF THE RIDGE OF LLIWEDD, SNOWDON, SOUTH OF LLYN LLYDAW.

W. E.



1. Felspathic porphyry.
2. Volcanic ashes of various kinds.
3. Compact blue felspathic trap, sometimes columnar.

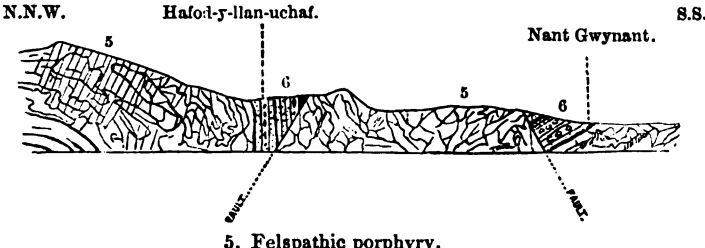
The curves of these rocks are well seen frem the miner's path on the north side of Cwm Dyli, and with a favourable light a good eye can easily follow the flowing sweep of the massive beds, and the outliers that rest on them and partake of their curvatures. These outliers are equivalents of the upper felstone of Gallt-y-wenallt and Crib-goch (Figs. 38 and 39).

The natural boundary between ash and felstone south-west of Llyn Gwynant nearly coincides with the run of the turnpike road as far as Llyn-y-Ddinas, south of which the ashes abut on the porphyry of Moel-y-diniewed and Mynydd Nant-y-mor, in consequence of a fault which throws them down on the east. Part of the section No. 3, pl. 28, crosses the road about half-way between Llyn-y-Ddinas and Pen-y-bryn.* Immediately west of the road to Hafod-y-llan-isaf, a triangular patch of the underlying porphyry appears at the surface. It is bounded by ash and entirely enclosed by faults, which are respectively downthrows on the south, east, and north-west. Their throw is uncertain, but if the trap be of about the same thickness that it is on Snowdon, and if where the section crosses little besides the ashy beds have been denuded from its surface, then the eastern downthrow may amount to 600 or even 800 feet. That on the north-west is more remarkable, for vertical beds of ash stand on end adjoining the porphyry east of Hafod-y-llan-uchaf. (*See* section No. 3, pl. 28). On the west the underlying porphyry also rises vertically, and immediately after, bending to the north-west, it sweeps along Cwm-y-llan towards the peak of Snowdon. The disposition of the rocks, as drawn in the section and in the following diagram, may appear improbable to those unaccustomed

Fig. 41.

SECTION ACROSS NANT GWYNANT, HALFWAY BETWEEN LLYN GWYNANT AND LLYN-Y-DDINAS.

N.N.W. Hafod-y-llan-uchaf. S.S.E.



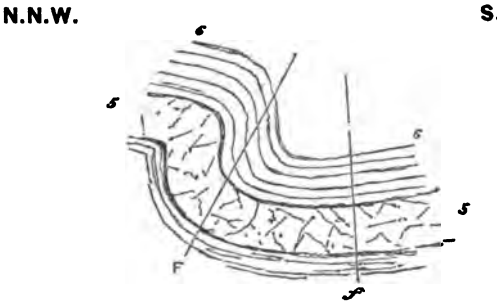
5. Felspathic porphyry.
6. Felspathic ashes, calcareous.

* *See also* 6-inch section, Sheet 28, line 4.

to the extraordinary positions into which rocks have often been thrown in highly disturbed districts; and at first it is difficult to understand how the lower edges of the vertical strata should abut on the faulted edge of the porphyry, which in its natural position should lie horizontally under the ash. The origin of this arrangement may be explained as follows.

Suppose the masses of rock to have been curved in the manner shown in the following diagram:—

Fig. 42.



Let 5 represent the porphyry, and 6 the ashy beds; then in the line of the fault *f* (supposed to represent the Nant Gwynant fault) let the beds be thrown down about 600 or 800 feet on the side marked S.S.E., and let those on the N.N.W. side slip down about 1,800 feet along the line F (the Hafod-y-llan-uchaf fault), the result would be that the ends of some of the beds of the ashy rocks would abut on the porphyry at the fault *f*, while another part of the same ashes would rest on their ends on the porphyry No. 5, at the fault F and this would be the case whether the faults were formed in consequence of the bending of the rocks or after the curvatures had been effected. Then the whole being denuded, the rocks assumed their existing surface arrangement.

Between the vertical rocks at Hafod-y-llan-uchaf and the top of Snowdon certain broad curves again bring in the ashes where the peak of Y Wyddfa* shoots into the air. Part of the dotted lines above the surface of the ground, in plate No. 28, section 3, show the denudation that these beds have suffered over part of this area, so as to separate the ash of Snowdon and Nant Gwynant. There can also be no doubt that they were once covered by a great thickness of Bala beds higher in the series, since removed by denudation. The trough-like curve is well shown in the section, in spite of the fault that on the west of Snowdon causes the ash to abut against the porphyry in the neighbourhood of Llyn-du'r-Arddu, and the still more serious breaks that lie between Cynicht and the peak of Snowdon. The highest peak in Wales thus lies in the centre of an irregular synclinal trough, the sides of which have been broken by faults, and vast masses of the strata have everywhere been removed by denudation.

From the top of Snowdon the ash extends midway down the crags to the heights between Llyn Teyrn and the top of the Pass of Llanberis. From thence, much faulted, its lower boundary sweeps along the rocky ground between Cribgoch and the Pass not far below the pools that lie in the higher upland valley of Cwm-glas, and passing along the eastern and southern sides of Cwm-glas-bach, it strikes across the valley less than a quarter of a mile above the turnpike gate. From thence it skirts the west side of Esgair-felen to Twll-du (above Llyn Idwal), where it curves round to the south-west, and crossing the road near Cwm Patric, trends by Llechog to Llyn-du'r-Arddu, near which the ashes are crossed by the section.†

On the south side of Crib-goch, the strata are partly composed of dark brown ashes and volcanic sand or of slaggy-looking lapilli mingled with scoriaceous fragments. Above Llyn Llydaw it is often highly calcareous and irregularly bedded, these qualities inducing a rough cavernous outline in the decomposing outcrop of the beds. The name of the lake has a possible connexion with the truly ashy appearance of some of the volcanic strata, for

* "The Conspicuous Head," the Welsh name for the top of Snowdon.

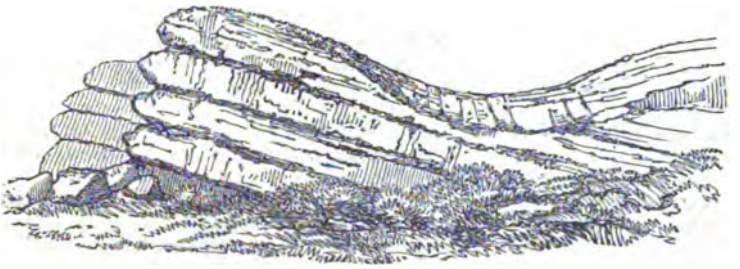
† Sheet 28, and plate 28, No. 3.

the word *Llydaw* is the Welsh name for Armorica, while Lludw is the Welsh word for ashes, and the black cinder-like character of some of the decomposing rocks might readily strike the eyes of persons totally unacquainted with anything like geological theory.

The sandy and calcareous character of some of these beds is especially marked to the westward of Peny-lan, between Llyn Teyrn and Gorphwysfa. It there decomposes into a brown earthy soil, like that near the north end of Llyn Gwynant, and the area of this variety is easily distinguishable by the freshness of its verdure. Characteristic sections occur on the north side of Crib-goch, almost equal to those that overhang Cwm Dyli.

In Cwm-glas the same kind of phenomena are well shown. Below the pools in that valley there is a steep descent formed of felspathic porphyry and greenstone, overlooking the Pass of Llanberis. The ashy lines (which may be followed by the eye even from the bottom of the Pass) crown this cliff, curving in sweeping undulations, and being often bare of vegetation, the brown weathered edges of the strata are strongly apparent.*

Fig. 43.



They are highly fossiliferous, yielding numerous casts of a large-ribbed *Orthis.*

Four triangular patches of felspathic porphyry overlie the ashes on Crib-goch. Three of these form the greater part of the crest of the ridge, and the fourth lies on its south slope. All of them occupy the same geological position as the patches of Gallt-y-wenallt, Crib-goch, and Lliwedd (Fig. 38, 39, and 40) already mentioned, the whole having originally belonged to one broad mass that spread itself above the ashes as far as Moel Hebog, and probably beyond (Fig. 44). On Crib-goch, two of them are each nearly half a mile in length, and the third, which lies between the others, is so small that it is scarcely distinguishable on the map. They lie in their present positions partly by the curvature of the strata and partly by complicated faults, which, in two instances, bring in juxtaposition the porphyries that lie above and below the ashes, once north of Glas-lyn by an east and west fault, and again, by a north and south dislocation, at the east end of Crib-goch. In both cases the throw cannot be less than from 1,000 to 1,200 feet.

Unlike the slaggy-looking porphyry that underlies the ash, the overlying trap is very compact and often columnar. When narrowly examined, the columns are not always very symmetrical, being generally four, five, and six-sided prisms, from 3 to 8 inches in diameter. The rock is full of joints, and its fresh surface is greyish blue. It rings under the hammer, and by disintegration breaks up with a sharp and flinty fracture, apt to cut the boots and hands of him who scrambles along the serrated ridge or across the steep and shingly slopes that surround the sharp peak at the eastern end of Crib-goch.

In these Cwms, rather than by the more accessible footpaths, the sections of this country can be best studied. Accordingly, on the path from Snowdon to Llanberis, the ashes by no means present themselves in their most typical form, being more calcareous, slaty, and sandy than ashy in texture, and containing here and there numerous fossils. *Orthis flabellulum* is plentiful, and in smaller quantity *O. Actoniæ*. The cleaved slaty structure is well seen at the summit of the mountain. Passing towards Llyn-du'r-Arddu, they become more felspathic. Between Cwm-y-llan, near the peak, and Llyn du'r-Arddu, the

* The surfaces of the rocks are here and in numerous other places beautifully polished and grooved by the ancient glaciers of Snowdon. (*See* "The Old Glaciers of North Wales," Ramsay.)

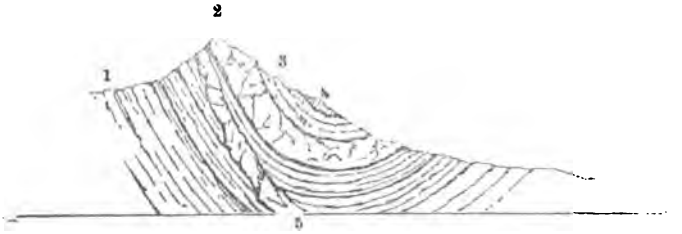
ashy beds dip north-westerly with gentle undulations at an average angle of about 5°, which on the cliff above the greenstone by Llyn-du'r-Arddu suddenly increases to 45°. These curves can easily be followed with the eye from the path that leads to Capel Curig.*.

Pass of Llanberis, Twll-du, &c.—On the north side of Snowdon, between Cyrn-las and Cwm-glas-bach, the country is exceedingly craggy, and the felspathic porphyry and ashes so much resemble each other that in mapping it is impossible to separate them without hammering along every yard of the line. The same is the case above Glas-lyn. Both ash and felstone are porphyritic and weather grey; but the ribboned slaggy structure of one, and the bedded nature of the other, become apparent when rigidly looked for, and above the Pass of Llanberis it is found that, after many minor undulations, trap and overlying ash dip westerly and rise again in a sharp synclinal curve in the picturesque cliffs of Llechog. This curve becomes more narrow as it approaches the Pass opposite Cwm Patric, but it again widens and curves round in a basin-form above Llyn Idwal at Twll-du. Near the bottom of Cwm Patric the ash is calcareous, and decomposes into a soft brown sandy earth; and above Twll-du it is chiefly a kind of felspathic slate, accompanied by a rubbly felspathic vesicular conglomerate, which forms the greater part of the broken ground in the upland valley above Twll-du.† In the more slaty varieties numerous fossils are found, characteristic of the Bala limestone, of which it is the representative. The following species are from the lists of Mr. Salter, made on the spot:—*Calymene brevicapitata, Cybele verrucosa, Trinucleus concentricus, Homalonotus bisulcatus, Lichas laxatus, Bellerophon carinatus, Holopella, Lituites planorbiformis, Orthoceras, Murchisonia scalaris, Ctenodonta, Orthis elegantula, Leptæna depressa, Orbicula, Tentaculites annulatus,* and *Favosites fibrosa.*

Such is a description, necessarily tedious when minute, of the ashy strata of Snowdon and Twll-du. The isolated patch that extends from Braich-y-Cornel over the summit of Moel Hebog to Moel Lefn resembles them. On Moel Hebog they lie in an inclined synclinal trough, and consist of the usual sandy, calcareous, and felspathic beds, in some places, especially near the base, brecciated or conglomeratic, and here and there fossiliferous. At Moel-yr-ogof the ashes are capped by two outliers of the same felspathic columnar trap that tips the ash of Lliwedd and Crib-goch. The disposition of the whole will be understood by reference to the following diagram from a drawing by Mr. Selwyn, who mapped that part of the country.

Fig. 44.

MOEL-YR-OGOF ON THE NORTH FLANK OF MOEL HEBOG.



1. Fossiliferous grits and slates equivalent to those of Yr Arddu (Dolwyddelan) and Cerrig-Cochion.
2. Felstone porphyry (slaggy looking).
3. Felspathic, brecciated, and calcareous ash, equivalent to the ashes of Snowdon, Dolwyddelan, and the Bala limestone.
4. Upper columnar felspathic trap.
5. Greenstone.

* The serrated outline shown in the section (Sheet 28, and pl. 28, fig. 3) are the consequence of the line on which the section was run across several of the minor ravines that run from the ridge towards Glas-lyn. The construction of such a section is a matter of considerable difficulty. Every foot of the line was chained, and the angles of the ground taken with the theodolite straight across the country, some of the ground traversed inclining at angles of 40° to 60°.

† *See* Plate No. 2, and 6-inch sections, Sheet 31, line 2, between Y-Glyder-fawr and Y-Garn.

CHAPTER XX.

THE SNOWDON AREA CONTINUED.

General Description.—Porphyries.—The volcanic ashes described in last chapter are underlaid by vast masses of felspathic rocks sometimes porphyritic, sometimes scoriaceous looking, sometimes what has been termed *slaggy*, the lines of viscous flowing being often as apparent as in the cooled slags of an iron furnace. The base of this rock is highly felspathic, and it often contains small isolated crystals of felspar. Its fresh fracture is blue or grey, and it weathers white or cream colour. The slates or grits on which the porphyries rest are altered at the lines of contact, generally only for a few inches, as may be seen on the precipitous cliff above Llyn-du'r Arddu, or at Cribiau above Llyniau-Duwaunedd, near Moel Siabod. The ashy beds above are quite unaltered, and this —and the perfect manner in which with the stratified rocks, the porphyry has been affected by all the contortions of the rocks of the country—proves that it is a great bed or rather a set of beds of felspathic lava *interbedded* with fossiliferous strata. In no sense are the felspathic porphyries of Snowdon the cause of the disturbance of the rocks of the country as it now exists, for, long after cooling, they have been themselves affected by these disturbances.

Nant Gwynant.—East of Nant Gwynant, and north and south of the point crossed by the section (No. 3, Pl. 28), fossiliferous slates and grits already mentioned dip under the porphyry of Cerig-Cochion and Cribiau (Fig. 38), which at its base is somewhat brecciated, as if while in the act of flowing its under surface had cooled somewhat rapidly, and the lava had broken up into scoriaceous fragments, to be cemented by inflows of melted matter which subsequently cooled. The slate on which the trap immediately rests is so highly altered that for a breadth of about a foot it is impossible to define their limits. South-west of Cerig-Cochion, on the hills east of Nant Gwynant, the trap stretches towards Beddgelert with a very irregular and faulted outline. It is of this part of the porphyry that the felstone rocks of Castell and Yr-Arddu between Moelwyn and Nant Gwynant are outliers.* (6-inch Sheet, Section 28, and No. 3, Pl. 28). They lie in well-curved troughs, and around and under them are slates and greenish grey grits, containing Encrinite rings and many other Bala fossils. These are the precise equivalents of the sandy beds under the igneous rocks of Dolwyddelan, and just as in the country between that valley and Manod-mawr the sandy beds form the higher part of the series, so between Moelwyn and Yr-Arddu the beds are slaty below and sandy and fossiliferous above, their entire thickness, exclusive of injected greenstones, being about 6,000 feet.

West of Castell and Yr Arddu the grits and slates dip E.S.E. from 20° to 40° as far as the jagged faults that bound the porphyry on the east from Bryn Gwynant near the lake to the neighbourhood of Pont Aberglaslyn. These faults cause the felstones to abut on slaty beds from 3,400 to 4,000 feet below those on which the same rock rests at Hafodydd-brithion,† Castell, and Yr-Arddu. Further south, about a mile east and south-east of Beddgelert, one of the faults must have even a larger downthrow (5,000 feet?) for all the felspar porphyry is cut out, and the ashes are brought into contact with the slates below the trap. This fault, also in part a copper lode, extends from Llyn-y-Ddinas to the hills about half a mile S.S.W. of Pont Aberglaslyn, where the felstone

* Six-inch section, Sheet 28, line 3.

† About 2 miles east of Llyn y Ddinas.

again abuts on the slaty and gritty beds below. Where the fault ceases the fossiliferous grits appear as far south as Y-Gelli-llydan, and the boundary line then passes west to Moel-ddu, and suddenly changing, strikes a little east of north by Beddgelert and Yr Aran to the very top of Cwm-y-llan immediately under the peak of Snowdon. Except near Moel-ddu, the whole of this boundary, from Beddgelert to Yr Aran, about 6 miles in length, is a fault, the porphyry being thrown down on the east against the blue slaty beds of Y-Graig-wen and Yr Aran in the manner shown in diagram No. 46. An unfaulted boundary line between the felstone porphyry and grits and slates then passes south-westerly across the ridge that unites Snowdon and Yr Aran to the neighbourhood of Cae'r-lloi on the Caernarvon and Beddgelert road, and from thence passes southward to Moel Hebog. Along this part of the boundary the rocks are associated with lines of intrusive greenstone. From the top of Cwm-y-llan (Snowdon) to the east side of Moel Hebog, Bala beds dip north-west and west under the porphyry; and between that part of the igneous rock that runs from Moel-ddu*, to Snowdon, and from Snowdon to Moel Hebog, the slaty rocks lie in the form of an anticlinal curve, the east side of which has been partly cut off by the Beddgelert and Cwm-y-llan fault.

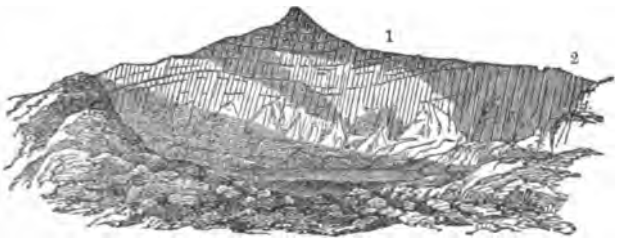
These masses of rock, however, immediately rise in a synclinal curve (Fig. 44, p. 148) which (as the ground sinks on the south side of Moel Hebog) causes the felstone porphyry capped with ash to curve rapidly round at Braich-y-Cornel. From thence the lower boundary line strikes about 4 miles due north with an eastern dip, underlaid by fossiliferous grits, and afterwards runs north-east to Clogwyn-du'r-Arddu, on the west flank of Snowdon, where, for the present, I shall leave the line.

Moel Hebog,—The disposition of the rocks on Moel Hebog has already been shown in diagram No. 44. The felspathic porphyries of that mountain and of Y Graig-ddu are of the usual type, and frequently possess that slaggy structure of twisted and straight lines that indicate the curving and stretching of lava in lines of viscous flowing.† The crags of Y Graig-ddu are intersected by patches of branching greenstones. North-east of this hill the ground is for a space covered by deep boulder drift, which from the bottom of the valley rises in long slopes up the sides of Yr Aran and Y Graig-wen. Rocky bosses, however, here and there project from the rubbish, sufficient to warrant the inference of the continuity of the rocks between Y Graig-ddu and the broken country west of Cwm-craigog.

Snowdon.—On the ridge of Llechog, west of the peak of Snowdon, the felspathic porphyry is curiously cleaved, or at least very closely jointed; and so marked is this above Cwm-y-Clogwyn that it is difficult at first to believe that it is part of the very same slaggy-looking masses previously described. So completely is the appearance of the felstone of Llechog, and of the cliff below the peak of Snowdon, modified by this structure, that there is the utmost difficulty in fixing on a boundary line between it and the overlying ash, both being felspathic and both cleaved and jointed.

Fig. 45.

PEAK OF SNOWDON, CLEAVED ASH AND FELSPATHIC PORPHYRY.



1 Ashy beds. 2. Felspathic porphyry.

* 3½ miles N.N.E. of Tremadoc.

† *See* p. 153.

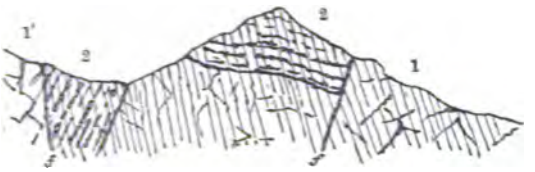
It is difficult to recognise the probability of intense cleavage being induced in a rock that has been melted, accustomed as we are to consider that cleavage of this nature is confined to stratified rocks. Less than 2 miles from this point, on the sides of Cwm-y-llan near Yr Aran, the same structure is remarkable, and it was not till after repeated visits and much study on the spot, that Mr. Selwyn was enabled to draw the lines of demarcation between the ashes and the felspathic porphyry.

Looking south the arrangement of the rocks on Geuallt is explained in the following diagram by Mr. Selwyn.

Fig. 46.

SECTION ACROSS PART OF GEUALLT.

N.W. S.E.



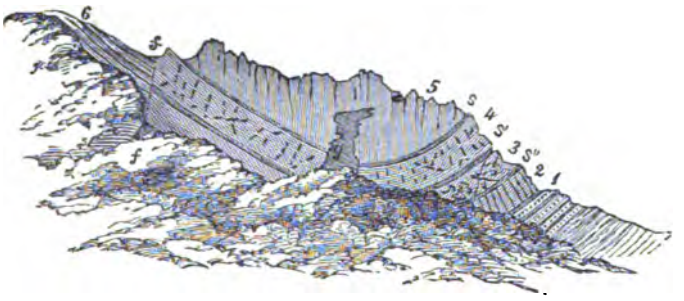
No. 1, on the south-east, represents the lower felspathic porphyry of the triangularly faulted area, about a mile south-west of Llyn-Gwynant.

No. 2, the felspathic ash faulted against this trap and rising to the west. It caps the porphyry, which here appears on the surface for about half a mile. The ashy beds 2 are then suddenly thrown in on the west by a rapid curve of the strata, and dipping westerly at a high angle they abut again on the same felspathic trap 1', in consequence of a fault (also a lode) which strikes from Cwm-y-llan S.S.W. across Geuallt and ends at a little fault about a mile north of Beddgelert.

I shall now resume the description of the north-west side of Snowdon, at Clogwyn-du'r-Arddu, where the structure of the rocks may be advantageously studied from Llanberis. North-west of the peak of Snowdon, the felspathic porphyry breaks up into four distinct beds separated by slaty bands, symptoms of which may be less distinctly observed in Cwm-y-Clogwyn, where certain hard grits are interbedded with the felstones, but on too small a scale to be noticed on a 1-inch map. Together they lie in a synclinal curve between Bwlch-cwm-Brwynog and the cliffs above the south-east angle of the dark little tarn of Llyn-du'r-Arddu, where they are cut off by the fault *f* of the following diagram, and the ashy beds 6 that form the summit of Snowdon are thrown against them.

Fig. 47.

SYNCLINAL CURVE OF CLOGWYN-DU'R-ARDDU, SNOWDON.



1. Gritty and slaty beds.
2 to 5. Felspathic rocks.
6. Felspathic ashy beds.
g. Greenstone.
s. Slaty beds.

Nos. 5 and 4 represent the chief parts of the masses of porphyry that underlie the ashy beds. They are here partly columnar, and the columns are generally perpendicular to the dip of its surfaces. Tortuous lines of viscous flowing, giving the rock, when closely examined, a slaggy aspect, are here strongly marked (Fig. 50). On the whole these wave in the direction of the dip. No. 3 is a coarse felspathic breccia, No. 2 a compact felspathic rock rudely columnar, and between each there are thin beds of slate, marked *s*.

The slate *beneath* each of these lava-rocks is much indurated, adhering firmly to them at the junctions; and occasionally for a thickness of 2½ feet they look as if they had been almost fused by the melted matter that flowed across them when they formed the muddy bottom of the Silurian Sea. They are in some places scarcely visible from below, but a good climber who wishes to study the effects of the porphyry on the slate may here and there follow one along the synclinal line till it is cut off by the fault near the summit of the cliff. They generally form the merest lines of separation. Beneath the lowest bed lie the same sandy and slaty beds (No. 1) that underlie the felspathic porphyry of all the area already described from Moel Hebog to Dolwyddelan. A greenstone dyke (*g*) pierces these rocks, probably connected with the round boss that borders Llyn-du'r-Arddu and forms part of the cliff above. It is largely crystalline. Some minor faults occur in it and the ash that it pierces, one of which is a copper lode which has for many years been occasionally worked and abandoned. Slate standing vertically, and probably brought there by the injected vein, occurs in the line of fracture. Passing into the body of the ridge of Clogwyn-du'r-Arddu, the same greenstone reappears in Cwm-y-Clogwyn, on the south side of the ridge.

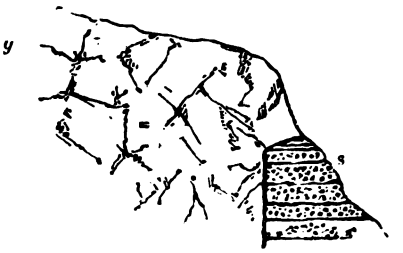
Fig. 48.

g. Greenstone. 2. Felspathic porphyry. *f*. Fault.

For a certain distance the felstone is brought against it by a continuation of the Llyn-du'r-Arddu fault *f*. On the cliff south of Llyn-y-nadroedd both stand in a vertical position, the felspathic porphyry being intensely jointed.

The greenstone here consists of felspar and hornblende in about equal proportions, though occasionally felspar predominates. South of Llechog it widens out and branches, one arm running through the felstone near the Beddgelert path, and the other striking in among the strata of slate sandstone and conglomerate that underlie the felstone near Llyn-y-Gader, Y-Craig-ddu and Moel Lefn, north of Moel Hebog. Though it here follows the general strike of the strata for several miles, forming in part of its course a long rocky escarpment on the moor between Llechog and the Caernarvon and Beddgelert road, its intrusive nature is proved beyond a doubt, not only by the large branchings

Fig. 49.



already alluded to, but also by the manner it (*g*) cuts through some of the minor grit beds (*s*) that west of Llyn-y-nadroedd are interstratified with the porphyry, and inseparable from it on so small a map. Fig. 49.

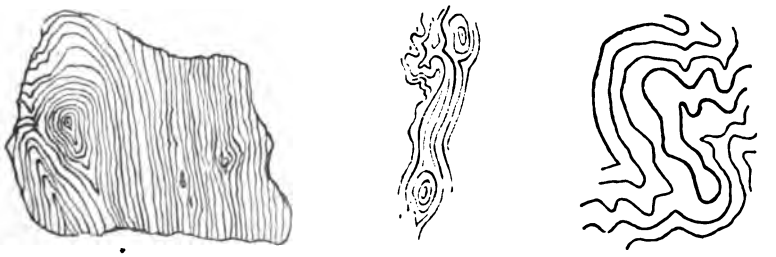
When intruded into the felstone the greenstone is readily distinguishable from it in consequence of its lighter hue, a peculiarity due to a covering of white lichens that generally flourish more luxuriantly on the more easily decomposed greenstones than on the harder and more siliceous felstone rocks, so that after a time, partly by their tints, and partly by help of distinguishable varieties of outline, the geological mapper can scarcely fail to observe, even at a distance, the presence of hornblendic rocks, though they may lie in the midst of the widely spread felspathic masses that form so much of the country.

From Clogwyn-du'r-Arddu the felspathic traps strike to the north-east, across the Pass of Llanberis, in three well-defined bands. The north and south fault that runs from Cwm-y-Clogwyn by Llyn-du'r-Arddu to Llechog (overlooking the Pass) appears to change rapidly in amount, and probably dies out before it reaches the Pass, though on Llechog, all the rocks being nearly vertical, this is necessarily uncertain. North-west of the peak of Snowdon the section (Pl. No. 28, Fig. 3)* crosses these rocks about midway between the summit of Llechog and Llyn-du'r-Arddu, and the actual positions of the ash and porphyry to each other is there partly inferred, but any one who considers the effect that such a fault must produce on dislocated masses of bedded rock passing by a rapid curve from a nearly vertical to a horizontal position, will admit the safety of the inference when studied on the ground.

The section at Llechog, like that of Clogwyn-du'r-Arddu, with a little clambering is easily accessible and peculiarly instructive, and were a geologist in doubt about the non-intrusive nature of the felspathic porphyries of Snowdon, there are no other places where he would be more likely to satisfy himself respecting their truly interbedded character, especially if he venture to follow the strike of the beds between the crags of Llechog, and Cwm Patric in the Pass of Llanberis. Throughout this course of less than a mile in length two well-marked thin slaty bands separate these beds of felspathic rock, and even from below with a favourable light, a good eye seizing the changing colours can follow them throughout. On the north-east side of the Pass, afterwards to be described, the slaty bands thicken and become more apparent.

On the summit of Llechog the uppermost mass of felstone crops out at an angle of from 70° to 80° dipping nearly east. The felspathic and calcareous ashes in immediate contact with it are very irregular in their dip, probably in consequence of the fault already mentioned, The porphyry is generally of a solid and massive character, and when weathered shows that wavy tortuous structure which I have called slaggy, and which I believe is in this rock due to the same cause that produces similar lines in some pitchstones, obsidians, pearlstones, and other non-crystalline recent lavas, or in the viscous flows that pass from iron furnaces in the form of slags. The accompanying drawings from large rocky fragments on Llechog, and at the base of Clogwyn-du'r-Arddu, show the nature of these lines.

Fig. 50.



In a mere drawing it is difficult to distinguish these *seemingly* foliated structures from the foliations of gneiss and mica-schists. In the rock the

* Also 6-inch sections, Sheet 18, line 2.

difference is obvious. In gneissic rocks there is more or less complete separation of constituent minerals into layers consequent on metamorphic action subsequent to the original deposition of the strata. In the case of these traps it is a structure induced by original viscidity and rendered permanent by consolidation.

The mass from whence the blocks were derived is about 900 feet thick, and rests upon from 50 to 70 feet of sandy felspathic beds, somewhat slaty in structure, which in their turn lie upon nearly 500 feet of compact felspathic brecciated and conglomeratic rock (the continuation of No. 3 in the Clogwyn-du'r-Arddu section, Fig. 47), containing fragments similar in form to those shown in the following diagram :—

Fig. 51.

When freshly fractured the stony fragments are generally indistinguishable or faintly seen, but on weathered surfaces they become very apparent. Both matrix and pebbles are porphyritic, and from its general character, I incline to the supposition that much of the rock may have originally been a scoriaceous lava, the irregularly formed small fragments and larger blocks being mingled with fine ashy matter that fell on and among them, the whole having since consolidated into a compact mass. Sometimes also it looks as if loose scoriaceous fragments on the surface became entangled in the moving lava stream, and, retaining their form, became imbedded in it. The yellow felspar crystals in the matrix are generally of irregular form, and like those of most ashes are fragmentary. The probability that the above was really the mode of formation of part of this rock is increased by the circumstance that in the continuation of the bed, and in the heart of Snowdon, there are no appearances similar to those now described, probably on account of the cooling having taken place under circumstances that did not admit of the formation of scoriæ.

The whole mass rests on about 100 feet of sandy rock, slightly mixed with ashy matter, which separates it from a bed of slaggy felstone 250 feet thick, similar in general aspect to that already described. This forms the lowest part of the igneous rocks of Snowdon, and it rests on beds of blue and brownish-grey grit and slate (equivalent to those of Moel Hebog and Dolwyddelan), beneath which are beds of blue slate, well seen along the ridge that overlooks the village of Llanberis.

Llanberis, Y-Glyder-fawr Llyn Ogwen, &c.

If we now follow the course of the Snowdon felspathic porphyries across the Pass of Llanberis, it appears that they strike steadily north-east to Llyn Idwal and Braich-du,* from whence they curve southward.† The lowest bed striking southerly from the crags of Braich-du above Cwm-Lloer, recrosses the valley by the bridge at the falls of the Ogwen, where the synclinal curve is uncommonly sharp, the rocks below the bridge dipping a little south of east about 80°, and rising again with a high westerly dip immediately above the waterfall. From this point the bed strikes south-east through Llyn Bochlwyd and over Y-Glyder-fawr to Llyn-y-Cwm-ffynnon, near the top of the Pass of Llanberis, where it thins out.‡ The bed of felstone next above curves round at Llyn

* North of Llyn Ogwen.

† Maps 75 N.E. and 78 S.E.

‡ The rocks of Y-Glyder-fach, Carnedd Llewelyn, &c. are lower in the series.

Idwal, and, crossing the summit of Y-Glyder-fawr, descends to the pass of Llanberis in that noble brecciated cliff from whence the massive ruins have fallen that give a name to Pont-y-gromlech.* From some points of view on the road, part of the broken crag stands out on the hill side like a huge tower, on which the great jointed surfaces from whence the ruins fell are distinctly visible on the vertical cliff above. The third and highest bed of the Snowdon porphyries as seen on Clogwyn-du'r-Arddu curves round on the cliffs between Llyn Idwal and below Twll-du, and forms the shelving slope of Esgair-felen, and that magnificent crag that, seen from the lakes of Llanberis, rises above Cwm Patric from the left of the road.

From the upper part of the Pass of Llanberis the continuity of these felspathic lavas with that of Cribiau and Cerrig Cochion is obvious, and this completes the circle of the felstone rocks that form the base of Snowdon, the description of which commenced when I showed its relation to that which underlies the ashes of Dolwyddelan (p. 140).

Between Llyn Ogwen and the Pass of Llanberis various smaller beds of felstone appear and thin out. Two of these lie immediately south of Llyn Ogwen, one west of Llyn Bochlwyd, and others in and above the Pass of Llanberis west of Llyn-y-Cwm-ffynnon. The grits that underlie the lowest felstone bed a little above the village in the Pass, increase in strength and importance as they approach Nant Francon and Llyn Ogwen, and the thin bands of slate interstratified with the felspathic rocks on Llechog thicken and pass into great masses of hard grit and arenaceous slate. They are strongly developed on either side of Llyn Ogwen, and at Llyn Bochlwyd, Llyn Idwal, and on both sides of Nant Francon below the falls, where they strike north up the cliffs of Craig-yr-hysfa, and south-west below the felstone of Y-Garn. As a whole, and especially in their lower part, they are the equivalents of the grits below the volcanic rocks of Dolwyddelan, Cribiau, and Moel Hebog, and contain the same general assemblage of fossils with these, and with the beds that lie below the porphyries of Y-Tryfan.

The diagram, Fig. 2, Pl. 28, shows the relation of the rocks east and south-east of Llyn Ogwen to those of Snowdon, and also of a beautifully regular basin above Llyn Idwal in the high ground between the Pass of Llanberis and Llyn Ogwen.

On the south-east are fossiliferous hard grey felspathic grits, No. 4, overlying the felstones 3, that a little further north form the heights of Y Glyder-fach and of Y-Tryfan.

Half-way up the broken slope the felspathic masses No. 3 roll over towards Y-Glyder-fawr in an anticlinal curve, the continuation of which further north, between Gallt-y-gogo and Y-Tryfan, is explained in diagram No. 33, p 133. The upper part of No. 3 is a felspathic porphyry, occasionally brecciated on its upper surface, but generally of a compact slaggy structure, full of agate-formed concretions. The lower part is also porphyritic, and in the middle there lie about 300 feet of felspathic breccias and ashy-looking conglomerates. On the south-east side of the anticlinal the whole mass of trap is about 1,000 feet thick, and nearly 1,300 on the north-west side, and west of the synclinal curve of Twll-du and Llyn-Idwal a part of it crops to the surface about a third of a mile west of Y-Garn in a band reduced in thickness, as shown by the dotted lines in the larger section† underneath the level of the sea. The same fossiliferous grit and arenaceous slates (containing *Strophomena expansa*, &c.) that lie upon the trap in Nant-y-Gwryd roll over to the west (4) and are succeeded by the hard blue felspathic trap (5) (the lowest bed of the Snowdon felstones) which, following the beautiful curve of the Twll-du synclinal, rises, reduced in thickness, on the peak of Y-Garn, where it is full of those small nodular agate-like concretions which are frequently so characteristic of the interbedded felstones of Caernarvonshire. The next porphyry of this section, which forms the summit of Y-Glyder-fawr (5′), is about 1,000 feet in thickness, and is a continuation of the middle band of the Snowdon section (No. 3, plate 28). The great felspathic lava beds, therefore, that run north from

* Or Cromlech Bridge, from the fancied resemblance to a Cromlech of the blocks fallen from the overhanging cliff. But there is no Cromlech there.

† *See* 6-inch horizontal section, pl. 31, line 2. Also No. 2, pl. 28.

Llyn-y-Cwm-ffynnon by Glyder-fach, Y-Tryfan, Gallt-y-gogo, and Carnedd Llewelyn to Conway, all lie in the Bala beds on a lower horizon than the felstone rocks of Snowdon. Bed No. 5′ is succeeded in ascending order by about 500 feet of arenaceous and argillaceous slaty beds, containing two distinct local bands of felspathic ash, which, however, are two small to be coloured in section 2, pl. 28. On these there rests about 300 feet of felspathic lava, forming, in the Pass of Llanberis, part of the great shingly slope of Esgair felen. On its upper surface, near Llyn-y-Cwn, it is slightly scoriaceous and brecciated, and the whole curving round above Llyn Idwal rises on the west, and strikes with rather a stratified look across the Pass of Llanberis, and up the cliffs of Llechog, forming the highest bed of the Snowdon porphyry. Between Twll-du and Llyn-y-Cwn this porphyritic lava is overlaid in the synclinal hollow by rocks marked No. 6 (fig. 2, pl. 28), which are formed of slaty beds, rubbly felspathic conglomeratic looking rocks sometimes scoriaceous, and sandy felspathic ash sometimes calcareous. These taken together are the northern continuation of the ashy beds that form the summit of Snowdon, and are therefore the general equivalents of the calcareous ashes of Dolwyddelan and of the Bala limestone of Bala, and the felspathic ashes immediately beneath it.

Fossils.—The fossils of this district are as follows, in descending order:—

The fossils of this ash above Twll-du have been already given ;* and in descending order the grits and slaty beds at the south end of Llyn Idwal contain the following species :—*Beyrichia complicata ; Trinucleus concentricus ; Bellerophon perturbatus ; Orthis flabellulum*, and Encrinite stems. The next gritty bands below 5′ run from the east side of Y-Garn across the middle of Llyn Idwal, and up Braich-du across Nant Francon, thence bending round along the east slope of Y-Glyder-fawr, near the top, they strike down to Pont-y-gromlech, and the west angle of Llyn-y-Cwm-ffynnon.† On the hills between this lake and Pont-y-gromlech, felspathic rocks (not shown in fig. 2, pl. 28), and the same fossiliferous grits, dip south-west at the angle of the slope of the hill under the great masses that form the slope of Snowdon in the Pass of Llanberis. The rock is concretionary, containing a number of agate-like nodules, somewhat chalcedonic, and the grits that rest on it sometimes convey the impression that the sediment had been spread on the surface of a scarcely cooled lava stream. On the north side of Llyn Ogwen the same grit widens out and forms the top of Braich-du, overlying the highest band of felstone on that side of the river. It contains *Strophomena expansa, Orthis flabellum, Cyclonema crebristria, Murchisonia angulata, Orthoceras*, and Encrinites. Lower still the grits, No. 4, below the felspathic lava of Y-Garn contain the same *Orthis* and *Strophomena* with the addition of *Leptæna sericea, Murchisonia scalaris, Raphistoma lenticularis, Rhynchonella*, and a *Fenestella ;* and below this, interstratified with still lower igneous bands, above the Holyhead road on the cliffs of Craig-yr-hysfa,‡ the grits and arenaceous slates contain the same general assemblage of organic remains. As a whole they represent those grits just above and beneath the Capel Curig porphyries that surround Llyniau Mymbyr. Besides most of the fossils named above they also contain *Rhynchonella Llandoveryana* in vast quantities, and in smaller numbers *Mytilus, Lingula, Favosites fibrosa*, and *Cornulites serpularius*, all species common to the Bala beds.

Greenstones.—I shall now explain in detail the mode of occurrence of the greenstone rocks on and around Snowdon.

These have heretofore only been incidentally alluded to. They are intrusive, and excepting a few narrow dykes, they are of Lower Silurian age. It is needless to describe each one ; but a few of the principal masses may be specially noticed. All of them are hornblendic. Between Pen-y-gwryd and Cribiau§ five patches pierce the stratified rocks and the overlying and interstratified felspathic porphyries. They lie on the same general geological horizon with those near Dolwyddelan and on Moel Siabod, in colour are dark green, and

* P. 148.
† The syllable *lech* of Pont-y-gromlech lies in this patch on the Map 75 S.E.
‡ Map 78 S.E., just above the Falls of the Ogwen.
§ Between the top of the Pass and Moel Siabod.

distinctly but not largely crystalline, hornblende predominating, and they alter the rocks with which they are in contact.

The line of greenstone about a mile in length that passes through Llyn-y-Cwm-ffynnon is well crystallized, slightly branching at its south-east end where the slaty rocks in contact with it are altered, and have been quarried for honestones. There are also several well-marked patches south of the Pass One of these (*g*, diagram, No. 39) when examined on the ground is seen to branch at both ends into several ramifications. These are well shown in the large knoll (a true roche moutonnée) above Blaen-y-pennant, where the greenstone pierces the slaggy felspathic trap in all directions in thin veins, in some of which, especially at their thin diminishing ends, there is much quartz, like those that so frequently proceed from masses of granite. At its junction with the felspathic porphyry the greenstone is often partially decomposed; its crystalline character is gone (probably from rapid cooling at its sides) and it possesses a flaky structure to so great an extent, that it sometimes looks like some of the cleaved decomposing dark green calcareous ashes, or in other cases assumes an appearance of a more slaty description. Another mass of greenstone beautifully crystalline breaks in among the rocks west and south of the twelfth milestone. A rock which makes honestones is in contact with it, originating probably in some short patch of slate associated with the felstone and altered by the greenstone.

A third boss about three-quarters of a mile across in all directions, forms most of the minor hills in Cwm Dyli and the hollow of Llyn Teyrn. The last is unusually felspathic for this district. Its well-marked columns may be seen from the Capel Curig path to Snowdon, near Llyn Llydaw, on an isolated hill that rises in Cwm Dyli between Llyn Teyrn and the brook that flows from Llyn Llydaw.

Another short patch lies at the top of Cwm-y-llan, a little S.E. of the top of Snowdon. One of the long lines that stretch towards Moel Hebog west of Yr-Aran lies partly in the felstone and partly in the highest sandy part of the Bala beds that dip under the felspathic porphyries. Though intrusive it dips like them north-westerly and rises again on the opposite side of the synclinal curve, in Cwm-y-clogwyn, where in two branches it lies, partly in the porphyry and partly in the underlying grits and slaty rocks north and south of Llyn-y-gader as shown in the following diagram.

Fig. 52.

Section West of Yr Aran, Snowdon, looking South.

1. Slaty and gritty beds.
2. Felspathic porphyry.
3. Greenstone.

Several other irregular bosses lie in the felstones of Y-Graig-ddu, north of Moel Hebog, which though very irregular in form and decidedly intrusive seem by signs known to the geologist to partake of the curvatures that have affected all the bedded rocks of this country, whether stratified or igneous.

North of the Pass of Llanberis there are several well-crystallized masses traversing the grits and felspathic porphyries; and a great vesicular, rubbly-looking patch forks across the rocks near the summit of Y-Glyder-fawr. A rock of similar character forms the top of Carnedd Llewelyn, and more massive in structure, rises like a great dark wall round the circular end of Cwm-llafar. These are not unlike the greenstone previously described, that,

on a lower geological horizon, forms the summit of Cader Idris.* One of the most striking bands begins on the hills less than two miles north-east of Llanberis church. It is partly columnar, and follows almost precisely the dip and strike of the slaty strata to Nant Francon, where crossing the valley, it ranges nearly in the same horizon up Craig-yr-hysfa, and curving round the edge of the north slope of Carnedd Dafydd, it strikes south to Afon Lloer, near Llyn Ogwen, still more or less agreeing with the strike and dip of the strata. Near the summit of Carnedd Dafydd it sends off a branch which, partly lying between the beds, trends south towards Llyn Ogwen, and the whole, though intrusive, clearly partakes of the synclinal curve, of which Braich-du is the centre. Seen only on the banks of Nant Francon along with another band a little further west, they might both easily be mistaken for true contemperaneously interbedded lava-flows.

The greenstones around Snowdon are perhaps all connected at no great depth beneath the surface by branching ramifications, but this is impossible to prove. They break out on different horizons in the Pass, in Cwm Dyli, Cwm-y-llan, Cwm-y-Clogwyn, and at Llyn-du'r-Arddu, yet, as already stated, they seem always to be affected by the curves into which the strata have been thrown subsequent to their intrusion; and it therefore seems probable, that like the great lines of greenstone in the country between Llanberis and Ffestiniog, and between Moelwyn and Nant Gwynant, their tendency has been to force their way in between the lines of bedding; but from causes difficult or impossible to trace, they have also branched underground hither and thither with considerable irregularity, and now when exposed by denudation, crop out apparently in a capricious manner.

Faults.—Some of the faults on either side of Nant Gwynant have already been described, and also those that run from the neighbourhood of Beddgelert to Llyn-y-ddinas and Yr-Aran (pp.144–146 and 149–152). It is scarcely necessary to enter into all the details of the effects produced by the faults drawn on the map of other parts of Snowdon; but as this is a district much visited it may be worth while to allude to a few of the more obvious. Where they most concentrate on the north-west of Glas-lyn several of them are copper lodes, one of which, generally striking to the north-west, and branching out in various directions, has been worked at intervals, and yielded a considerable supply of yellow sulphuret of copper. The long lines of white quartz, that like streaks of snow, contrast so strongly with the dark cliffs above the lakes, are all in lines of fracture, some of which are faults. Between Snowdon and Pen-y-lan there are 19 dislocations, which, on such rough ground, it cost me much labour to understand and map, and which are of importance, for they often throw the strata up or down several hundreds of feet, and without the faults the relations of the masses to each other would be unintelligible. One north-west fault passes from the hill above Llyn Teyrn towards the pass of Llanberis. It is a downthrow on the west, and brings sandy and calcareous ashes against the *lower* felspathic porphyry. About half a mile west of this, in a direction a little west of south from the twelfth milestone, several faults dovetail beds of pure sandstone (belonging to the ashy series) into the same porphyry. Several east and west faults also considerably affect the country. One above the eastern half of Llyn Llydaw throws down brown sandy calcareous and scoriaceous ashes to the south, cutting out a considerable portion of them at the surface. Another which passes along the south side of Crib-goch towards the copper lode, throws the *upper* columnar felstone down upon the ashy beds; and a third, which passes through Glas-lyn is a downthrow on the south, which in conjunction with a north-west fault that ends in Llyn Llydaw, lets in a small triangular piece of the same columnar trap on the southern slope of Crib-goch. A north and south fault passes along the steep slope of Crib-y-ddysgyl. It is a downthrow on the east, which above Glas-lyn brings the upper columnar trap against part of the ash, while on the west side of Cwm-glas the ash is thrown against the underlying porphyry that forms the great mass of Snowdon. Besides these there is the dislocation that runs north and south from Cwm-y-Clogwyn, through the east end of Llyn-du'r-Arddu to Llechog above Llanberis. This is a downthrow on the east, and though sufficiently

* *See* p. 35.

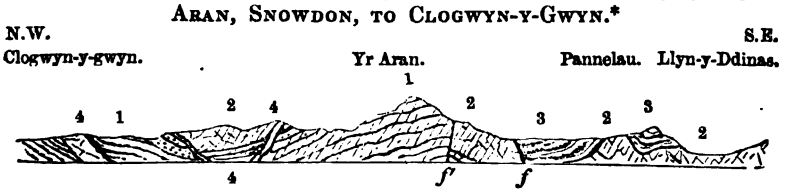
obvious when the rocks are simply inclined, where they become vertical on Llechog it necessarily becomes inappreciable. A branch of this fault, which cuts through the greenstone to the south-east, is a copper lode, and has occasionally been worked. The lower part of the Pass of Llanberis itself runs in a line of fracture, inappreciable when the beds are vertical (as between Cwm Patric and the village), but plain when the rocks are inclined or contorted lower down the Pass by the lakes.

Summary.—By help of the one-inch maps* and sections, especially that which crosses the peak of Snowdon (pl. 28, No. 3), and of fig. 38, p. 141, it is not difficult to explain the order and relations of the masses of rock that form the mountain, and the heights and valleys in its neighbourhood. Slate and fossiliferous grits of the Bala beds lie at the base of the mountain; three great beds of felspathic porphyry (which southwards converge into one) lie upon these; still higher are beds of felspathic, sandy, and calcareous ashes; and highest of all are the relics of a sheet of felspathic lava, here and there perched on the ashes in out-lying fragments (figs. 38, 39, 40 and 44). The Snowdon section in the plate shows all of these except the last, and it also gives a good idea of the steepness of the mountain, and the original sweeping though now broken curves into which the beds have been thrown. One of these, under the north-east side of Cwm-y-llan, brings the fossiliferous sandy beds within a few hundred feet of the surface. A little further south the same denuded curve, faulted on the east, actually brings the slaty beds that lie beneath the porphyry up to form the peak of Yr Aran.

Before leaving the subject, I shall show the arrangement of the rocks on a line of section between Llyn-y-Ddinas, near Beddgelert, Yr Aran, and Clogwyn-y-gwyn, west of Snowdon, in the hope of clearing up any difficulty that may remain in understanding the structure of the country, especially the relation of the Nant Gwynant rocks, with those of Yr Aran and the ground east of Llyn Cwellyn.

Fig. 33.

SECTION FROM THE NORTHERN END OF LLYN-Y-DDINAS OVER YR ARAN, SNOWDON, TO CLOGWYN-Y-GWYN.*



1. Slaty and sandy beds of the Bala series.
2. Felspathic porphyritic lavas.
3. Calcareous and felspathic volcanic ashes = Bala limestone.
4. Greenstones.
f. Faults.

The great sheet of felspathic porphyry No. 2, lies on either side of Llyn-y-Ddinas, and rising in a steep escarpment on the north-

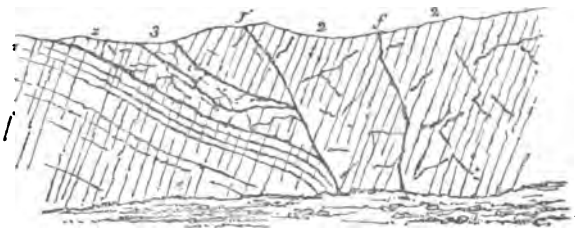
* 75 N.E. and 78 S.E.

† The south-east half of the diagram is from a sketch by Mr. Selwyn, the rest by myself.

west dips under wavy beds of the same ashy material (No. 3) that forms the peak of Snowdon. On Pannelau a tongue of trap 2′ again rises in a sharp anticlinal, being overlaid on both sides by felspathic volcanic breccia and ashy slates (3). On the north-west side of the axis they dip in that direction with a waving line, and suddenly abut on the underlying trap 2, which is brought in by the Geuallt fault *f* already mentioned.* This fault is therefore a downthrow on the south-east.

The felstone is highly jointed, the planes dipping W.N.W. about 70°. A little further, on the east side of Yr Aran, the line crosses the Cwm-y-llan and Beddgelert fault *f'*, also a downthrow on the east, of amount so considerable that the felspathic trap 2 is made to abut on grey and blue slaty and sandy beds No. 1, which in their natural position would be about 2,000 feet underneath the porphyry. The sharp peak of Yr Aran is formed of these strata dipping north-westerly from 20° to 35°. The planes of cleavage are inclined in the same direction about 50° to 60°, and slate quarries have years ago been opened in the strata, which proved of little value. West of Yr Aran fossiliferous slates and grits plunge under the long broad strip of felspathic trap 2 that unites Snowdon and Moel Hebog, and with a synclinal curve again rise on its western boundary, near Llyn-y-gader. They are associated with lines of greenstone 4, already described (fig. 52). This curve is part of the long bend that underlies the peaks of Moel Hebog and Snowdon, and of Braich-du, above Llyn Ogwen. On the west side of the upper end of Cwm-y-llan the dip of the rocks and the north termination of the greenstone may be seen on the cliffs, where it thins away in the manner shown in the following diagram by Mr. Selwyn.

Fig. 54.



1. Slaty and sandy beds of the Bala series.
2. Felspathic trap, much jointed, and columnar between the faults.
3. Greenstone.
f. Faults.

The diagram, fig. 53, when thoroughly understood, ought to give a clear idea of the ground on the south side of Snowdon which at first sight is not very intelligible. But, for a general understanding of the whole of the Snowdon section, any one with

* Three-quarters of a mile south-east of Yr Aran.

a good geological eye may grasp the entire order of succession during a walk up the Pass of Llanberis. First and lowest in the series, on the banks of the lakes are the Cambrian rocks, and above them the Lingula flags and Llandeilo and Bala beds,* then come the felspathic porphyries and ashes that form the crest of the mountain. Let any one who wishes to get a clear idea of the great thickness of the igneous series of Snowdon stand between the turnpike gate and Pont-y-gromlech, and with a favourable light he may see on the right the great tiers of various rocks that, piled on each other, lie between the bottom of the Pass and the topmost peaks of Crib-goch, as shown in fig. 39. First, resting on beds of grit (4), there are the solid masses of porphyritic and slaggy-looking felstones (5), here and there pierced by greenstones (*g*); and far up the mountain is a great black cliff, on the top of which thick beds of calcareous ashy rocks (6) undulate along in clear wavy lines that to the practised eye show a structure markedly different from that of the underlying massive rocks, or of the crags of upper columnar felspathic rock (*c*) that crown the ashes on the sharp ridge of Crib-goch.

At first sight it might be supposed that above Pont-y-gromlech the mass of the lower porphyry is far thicker than the same rocks lower down the Pass, on Llechog, since from the road looking up to Cwm-glas the felstone forms the great mass of the mountain. But this is partly deceptive, for the rocks, as drawn in fig. 39, p. 144, are highly inclined on the southern side of the Pass, thus increasing their apparent mass, and the greenstone *g*, rising nearly vertically as a sort of lofty wall, assumes an importance greater than its size would entitle it to in most other positions. Foreshortened from below, this slope looks as if almost inaccessible. Nevertheless, a ledge passes along its upper boundary, and the reversed dip (from 60° to 80°) of the intruded rock is shown in some places against the wall of felspathic porphyry that rises on the south side of the ledge. Seen on the spot, one cannot doubt that before its denudation the greenstone rose against this wall much above its present limits.†

The columnar trap *c* of the diagram 38, p. 141, is one of those isolated patches already frequently alluded to. The peak of Snowdon (Penwyddfa) barely escapes being capped by it. Always exhibiting the same sharp and columnar structure, and unconnected by dykes with any lower lying mass of igneous matter, it occurs in eight distinct patches, resting on the surface of the ashes. Two of these are on Crib-goch, fig. 39, three on the opposite side of Llyn Llydaw on Lliwedd and Gallt-y-wenallt (diagrams Nos. 38 and 40), and two on the north slope of Moel Hebog (diagram No. 44, p. 148), and one possibly above Twll-du west of Llyn-y-cwn; and I cannot doubt that the whole of the ashy beds of this area were once covered by a sheet of felspathic lava,

* *See* Section No. 3, pl. 28.

† This wall is several hundred feet above the Pass, and in some places it is polished and deeply and regularly grooved in an east and west direction by glacier action.

of which these small scattered patches are all that denudation has left to attest its former existence, perhaps on a scale as great as the porphyritic rocks that over an area of at least 60 square miles are known to underlie the ashes.

The thickness of all the igneous rocks on Snowdon may be estimated as follows in descending order :—

Columnar felspathic trap - -	200 to 300 feet.
Ashy beds - - -	1,200
Basement, slaggy and brecciated felspathic porphyries - -	1,700
	3,100 feet.

The whole easily divides itself into these three principal masses, but it is not therefore to be supposed that they are the result merely of three eruptions. Though under the greater part of Snowdon the lower porphyries coalesce and form one great mass, yet further north it has been shown to consist of at least three distinct lava-flows, interbedded with thick bands of fossiliferous grits and slates, indicating a long period of repose between the eruptions. It may have been that where the sheets coalesce the volcano for a space was elevated out of the water. Neither is it certain that each of the sheets was the effect of one flow. The 1,200 feet of ashy matter were clearly the result of gradual accumulation during intermittent eruptions ; for while some of the beds consist of purely felspathic dust, mixed with broken crystals of felspar, and others are made of agglutinated cinder-like stones and lapilli, others are intermingled with every variety of common sedimentary sand, mud, and calcareous matter, with occasional bands of fossils that evidently lived and died on the spots where they were entombed. It is not even likely that all the ashy matter was directly showered through the air into the sea, but rather that much of it was recomposed, having first fallen on land around one or more volcanoes, from whence, mixed with ordinary sediments, it was spread abroad in the manner of other strata by the effects of marine denudation.

Whether the columnar trap above the ash was produced by the last eruption of the volcano that vomited the igneous rocks of Snowdon, or whether it was followed by other lava streams and beds of ashes, there is no way of discovering. On the left bank of the Conwy (10 miles off), and in Merionethshire, above the horizon of the Bala limestone, all the rocks are formed of ordinary sediments without any volcanic admixture; and such as it is, this evidence would rather tend to show that the eruption that gave birth to the upper columnar trap of Snowdon was one of the last acts of the volcanoes of the area.

CHAPTER XXI.

The Lower Silurian Rocks of the Passes of Llanberis and Nant Francon, continued, and the Country between Llanberis, Criccieth and Clynnog-fawr.

General Description.—Beneath the igneous rocks of the Snowdon range, and between that mountain and the Menai Straits, there lies a thick series of strata which, as a whole, correspond in their greater features with the Cambrian rocks of Merionethshire, and at least in great part with the overlying strata as high as the horizon of the equivalent of the Bala limestone in Dolwyddelan and on Snowdon and Moel Hebog.

Fine sections of the Silurian strata are exposed in the high ridges on either side of Cwm-llafar, Nant Francon, and the Pass of Llanberis, one of the best being that on the south-west side of the Pass between the ridge of Llechog and the lakes.

With the exception of the fossiliferous sandy beds that immediately underlie the porphyries, the strata for three-quarters of a mile consist of dark blue and grey slate, dipping south-east from 60° to 80°, below which lie the grits and slates of the Lingula flags. Rising from under these, at the upper end of Llyn Peris and in Nant Francon, are the unfossiliferous conglomerates, grits, and purple slates of the Cambrian series, in which lie the great slate quarries of Llanberis and Penrhyn. These are the equivalents of the rocks between Harlech, Trawsfynydd, and Barmouth. Beyond Nant Francon the same Cambrian and Silurian rocks trend to the north-east towards Aber and Conway, and south-west of the lakes of Llanberis they form the country to the shores of the bays of Caernarvon and Cardigan.

North-east of the Pass of Llanberis, as far as the country near Aber the Lingula and Cambrian grits, separated by slates of the Lingula flags, run in lines nearly parallel, dipping easterly from 45° to 70°. They form a marked feature in the physical structure of the country rising between Llanberis and Nant Francon in the bold ridges of Elidyr-fawr and Carnedd-filiast, Elidyr-fach and Bronllwyd. The same rocks trend from Llanberis south-west to the shore of Caernarvon Bay north of Yr Eifl.

The interbedded porphyries and ashes of the Arans and Moelwyn in Merionethshire are, however, unrepresented in Caernarvonshire. If they existed their place in the series would lie somewhat above the Lingula grits that strike north from Llanberis along the ridge of Elidyr-fawr; but they have all thinned away deep under ground in the hollow of the great trough that lies between the igneous rocks of the Moelwyn range, and the western slopes of Moel Hebog, Snowdon, and Carnedd Llewelyn. Neither are the equivalents of the Tremadoc slates and Arenig beds certainly known in this quarter though there is at all events some reason for the belief that the Arenig strata may be present. If they exist in the Passes of Llanberis and Nant-francon their place should be somewhere not far above the Lingula grits of Elidyr-fawr. Either like the above mentioned igneous series the Tre-

madoc slates have thinned away in the trough, or they have been unconformably overlapped, or they are unfossiliferous, or if fossils exist they are still to be discovered.

The great mass of felspathic porphyry of Llwyd-Mawr is a broad outlier of the Snowdon porphyry, and between Llwyd-Mawr and Moel Hebog the masses roll over in an anticlinal curve, fig. 59, p. 170. Fossils seem to be rare in this area till we approach the country south of Moel Hebog. North-west of Llwyd-Mawr slaty Silurian strata dip south-east at a high angle under the porphyry, and no fossils have yet been found in them.

Between Llanllyfni and Aber, various intrusive masses lie amid the Silurian rocks, the most remarkable of which form the mountain of Mynydd-Mawr by Llyn Cwellyn, Moel Perfedd and Bwlch Cywion on the west side of Nant Francon, and Y-Foel-frâs near Aber. A great mass of felspathic quartz-porphyry also lies among the Cambrian rocks between Llanllyfni and Bethesda, and another crystalline mass stretches from Caernarvon to the neighbourhood of Bangor.

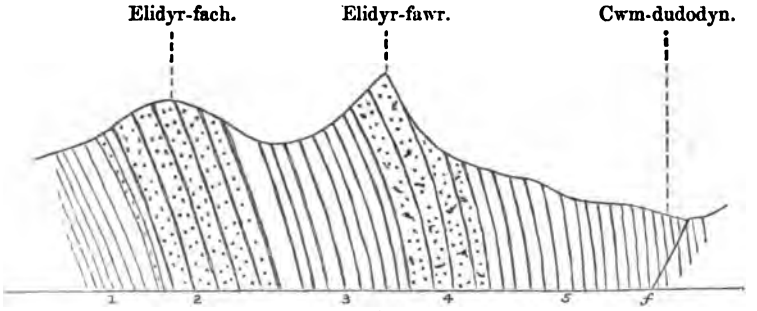
Llanberis and Nant Francon.—Everywhere in the Passes of Llanberis and Nant Francon the slaty rocks are so intensely cleaved that the bedding cannot be detected without rigid examination, especially since the bedding and cleavage nearly coincide. The strike varies from 30° to 45° north of east, and the rocks dip south-easterly about 80° and upwards. On the summit of the ridge, close to Y-Tryfan, Llanberis, the stratification seems nearly vertical. (Section pl. 28, No. 3.) On the slope, half-way down towards the Pass, a large gallery was excavated, in the hope that the quality of a certain vein of slate would improve in the body of the hill. When the geological lines were laid on the map it had been abandoned for years, but was for a time again in operation. In the Pass of Llanberis no fossils have been found in the beds between the sandy strata immediately below the felspathic porphyry and the Lingula flags, though cleavage and bedding nearly coinciding, there is no apparent reason why shells or their casts should be obliterated. As already stated it is therefore impossible in this region as yet to identify the Tremadoc slates, and if Arenig and Llandeilo beds be present (as I believe the latter to be) it is here impossible to draw a precise line of any value between them and the fossiliferous Bala beds, seeing that the lithological qualities of the very same sandy and slaty strata are constantly being interchanged in the line of strike.

Between the Pass of Llanberis and Nant Francon the slaty beds above the Lingula grits strike across the ridge of Foel-goch and Bwlch-y-breccan into Nant Francon, and are there easily divided into two masses, separable by their colours. The lower part on the north-western side of the fault is light blue, and the higher part of the section between the fault and the interbedded grits and felstone porphyries is, first light bluish and brown slates, passing upward into dark blue slate, sometimes almost black. Excellent sections showing the same succession occur on the opposite side of Nant-Francon on Pen-yr-oleu-wen above Ty-gwyn, and

also in Cwm-llafar and Cwm-gaseg. On the cliff of the latter valley below Yr-Elen the different coloured beds are exposed, abutting on each other on either side of the fault a little east of the peak, which there throws the strata down on the east about 1,000 feet, in the manner shown at the west end of diagram No. 35. Beneath the fossiliferous grits of Snowdon, Y Garn, and Carnedd Dafydd, the slaty part of the strata above the Lingula grits seems almost unfossiliferous, for though frequently searched by Mr. Salter and myself, only one undeterminable graptolite was found, and the same seems to hold good of the equivalent strata northwards to Aber and Penmaen-Mawr.

Under these circumstances, there is room for differences of opinion as to the precise equivalents of some of the strata in this mountainous part of Caernarvonshire. The Menevian beds have not yet been identified underlying the Lingula beds of Llanberis and Nant Ffrancon, though it is not unlikely they may yet be discovered, and the same is the case with regard to the Tremadoc slate which usually overlies the Lingula beds. Persons familiar with Merionethshire sections would naturally look for fossiliferous Tremadoc slates at No. 5 of the following diagram overlying the Lingula grits at Elidyr-fawr and Cwm-graianog.

Fig. 55.



1. Cambrian slates.
2. Cambrian grits.
3. Lingula flags.
4. Lingula grits.
5. Overlying blue slate.

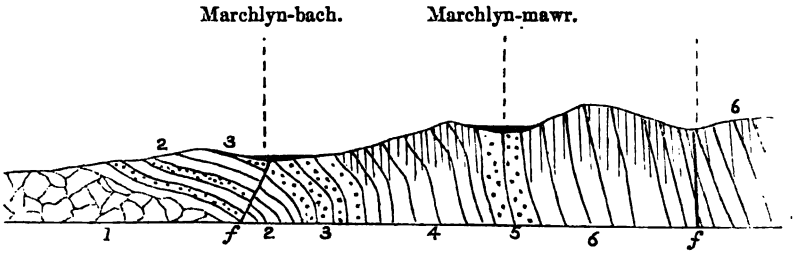
In the absence of fossils, though well searched for by experienced collectors, I cannot identify the argillaceous light blue slates that rest on the Lingula grit with the Tremadoc slates which they do not much resemble lithologically, and Mr. Etheridge, to whom I showed the section in 1875, agrees in this opinion. If not of that age then they may be Arenig beds, or Llandeilo slates, and where unbroken by faults further south it is certain that they pass conformably into the overlying dark blue slate, which in their turn pass regularly up into and are interstratified with the fossiliferous grits of the Bala series.

Lingula Beds.—Taking the Pass of Llanberis as a starting point, I shall now describe in more detail the Lingula flags northward to Aber and southward towards Clynnog-fawr.

Crossing Y-Tryfan on Snowdon above the village of Llanberis there is a fault supposed to be about 30 miles in length, which runs from Llandbedr, near the valley of Conwy, to near Dolbenmaen. On Y-Tryfan it is marked by fractures filled with quartz, and the lower part of the overlying strata is

thrown down on the east against hard quartzose Lingula grits, which dipping south-easterly are cut off by the fault before they reach the base of the hill. (Section 3, plate 28, and 6-inch sections, sheet 28, line 2.) On the opposite side of the Pass, the grits reappear at the eastern end of Llyn Peris, in a vertical or even slightly reversed position. Here in some minor fractures spots of greenstone occur, and the main fault forms the eastern boundary of the grits for about half a mile. Below them on either side of Llyn Peris are slaty Lingula beds on end, about 1,000 feet in thickness, and resting on Cambrian grits. From the Pass, the Lingula grits trend a few degrees east of north, in the form of thick quartzose beds and conglomerates, interstratified with slaty bands. They dip easterly at high angles, and, being less easily denuded than the overlying and underlying slates, by their hardness they form the sharp ridge of Elidyr-fawr, on which they are about 1,300 feet thick. From the bottom of the Pass the beds in inclined tabular masses may be seen cropping distinctly out and ranging far up the mountain, on which great shivered blocks lie piled on each other in ruinous confusion, rendering the ascent unusually toilsome. At the north end of Elidyr-fawr the whole series may be observed bed by bed striking downwards into the hollow of Marchlyn-mawr, and dipping east at angles of about 60° to 80°. A good section both of Cambrian and Lingula beds is exposed on the southern cliffs of Marchlyn-bach and Marchlyn-mawr as shown in the following diagram.

Fig. 56.



On the north-west there lies part of the great mass of felspathic quartz porphyry No. 1, which stretches from Llanllyfni across the lower part of the Pass of Llanberis to Nant Francon near the Penrhyn slate quarries. This is overlaid by a low part of the Cambrian purple slates and interstratified grits No. 2, and beyond the fault *f* there lies the great uppermost mass of Cambrian grits No. 3, about 1,700 feet in thickness. Above these lie the Lingula beds No. 4, which between the Cambrian and Lingula grits (5) consist of slates weathering light brown or drab dipping east with vertical cleavage. Towards their base the Lingula grits No. 5 are somewhat slaty, but the main mass of about 1,100 feet thick consists of grey and brown grits, occasionally conglomeratic, in which, near the base on the south margin of Marchlyn-mawr, I found *Lingulella Davisii* and *Olenus micrurus*. It is worthy of remark, as showing the uncertainty of discovering rare fossils, that when in 1848 I mapped these rocks this *Lingulella* and *Olenus* were knocked out at the first blow of the hammer, and though in this locality the beds have since been systematically examined for organic remains, both by myself and others, not a single additional fossil has rewarded the search.* The overlying slates No. 6, between the Lingula grits and the interbedded felspathic porphyries of Y-Garn and Y Glyder Fawr, are shown in Fig. 2, Plate 28. They are of the Llandeilo and Bala or Caradoc series unless it should some day appear (what is not yet proved) that a low portion of them belong to the Tremadoc and Arenig series.

A clear and characteristic section of Lingula grits, occurs on the hills overlooking Nant Francon. Standing on the ridge of Carnedd-filiast, an immense bare shelving surface of rock, covered with large wave-like ripple or current marks, strikes the eye, dipping a little south of east about 36°, and forming a considerable portion of the higher part of the west side of Cwm-graianog. Further down I found in 1848 numerous casts of *Cruziana semiplicata* and

* Part of the country between the lakes is cumbered by great heaps of moraine debris.

other great *annelide* tubes on the rippled surfaces, both in the rocks in place and on the large fragments that strew the centre of the valley, and form the symmetrical moraine across its mouth (plate 3).

From below, on the Holyhead road, looking south-west from the 32nd milestone, the whole series is visible, striking in distinct beds from Moel-perfedd and Carnedd-filiast down to the large *roches moutonnées* on the bank of the river Ogwen. In the opposite direction for two miles the grits are also easily traceable across the hills by Bwlch-hela to Garth, where they are cut off by a fault (a downcast on the north-west) of about 2,000 feet, which seems to throw them against the north end of the line of the Cambrian grits a little west of Tan-y-garth. Their precise relations are, however, obscure, owing to the thick drift that covers the valley of Afon-ffridd-lâs. *Lingulella Davisii* in great numbers was found in the grits near Tyddyn-du in the lower part of Cwm-llafar (plate 2).

North and west of the fault the Lingula grits and slates are distinctly traceable to Moel Wnion, and between that hill and Aber they are repeated in a singular manner by five faults, the nature of which will be described, p. 202. Throughout this long course traced from the Pass of Llanberis, the mass of the grit north of Nant Francon gradually begin to get thinner. On Maes-y-gaer the last of it is seen in a sharp anticlinal roll north of the Aber river underlaid by grey banded slaty Lingula flags, and overlaid by other slaty beds which must be equivalent to the strata that overlie the Lingula grits of Elidyr-fawr. Along all this long strike from Llanberis northward, the grits are underlaid by about 800 or 1,000 feet of dark blue and often ferruginous slate, which separates the grey grits of the Lingula series from the underlying green and purple rocks of the Cambrian area. In this lower part of the Lingula beds no fossils were found by me in this part of Caernarvonshire.

Between Y-Tryfan in the Pass of Llanberis and Llyn Cwellyn on the south-west,* the Lingula grits so prominent on Elidyr-fawr, are suddenly lost. This on Y-Tryfan may be easily accounted for by the fault which crosses the hill, and being a downthrow on the east of considerable amount suddenly cuts out the grits by throwing the overlying slaty beds against the Lingula strata below. Beyond this, however, the detailed structure of the country is for a space very obscure, the rocks being over wide areas hidden under glacial debris, and partly because much of the ground is heathy and peaty. It is possible that they thin away, or pass into slaty material, or it is also not unlikely that as the strike of the country is here much disturbed, parts of the series may be cut out by undetected faults, probably continuations of some of those that so thickly intersect the hills overhanging Llyn Peris.

South of the valley of Llyn Cwellyn the relations to each other of the Silurian divisions is in places still obscure; but south of Mynydd-mawr in the valley of Nant-y-llef or Nantlle, certain grits and slaty beds appear, which in 1848 when I surveyed the country I considered to belong to Lingula flag series, and which are so described in the first edition of this memoir.

On the broken slopes on the south side of the valley between Llyniau-nant-y-llef and Llyn-y-dywarchen, the beds form a domelike anticlinal curve, the ends of which have been broken and cut off by faults. The eastern fault is probably a continuation of that which crosses Y-Tryfan, from whence, for the greater part of the way, it may be doubtfully inferred by quartz fragments on the surface, but the rocks being of similar quality on both sides of the fault, it is impossible to prove any actual displacement. Between Llyn Cwellyn and Llyn-y-dywarchen the grits of Clogwyn-y-gareg dip north for about an eighth of a mile, and N.N.W. towards the fault and copper lode, where the overlying strata in the bottom of the valley are thrown against them. From thence the grits full of minor cracks may be traced westward to Tal-y-mignedd, where dipping at high angles to the north and west they curve southward on the western slope of the mountain, where they are cut off by an east and west fault which throws down the slaty Bala beds against them on the south.

This fault crosses Cwm-y-ffynon† about half a mile below the spring, and another strip of the same grits appears abutting against the fault, and dipping S.S.E. on the southern side of the arch. It thus happens that the faulted

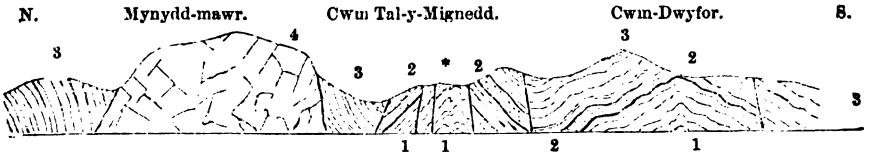
* Map 78 S.E. and 75 N.E.

† Ffynnon signifies a well or spring.

ends of the grits and the slaty Bala beds on opposite sides of the fault are brought for a space together, and this also occurs on the north-west slope of Y-Garn and on Clogwyn-y-gareg. The following diagram shows the arrangement of these strata on a north and south line drawn across Mynydd-mawr to Cwm-Dwyfor, a hollow the drainage of which forms the source of the stream that passes down the long valley bounded on the east and west by Moel Hebog and Llwyd-mawr.

Fig. 57.

SECTION FROM MYNYDD-MAWR TO CWM-DWYFOR.



No. 1 represents the lowest slaty beds, and No. 2 the grits in Cwm Tal-y-mignedd and Cwm-Dwyfor, No. 3 the overlying slates, and No. 4 the great intrusive boss of Mynydd-mawr. The slate that underlies the grit is here, pale grey and much lighter in colour than the blue slate which overlies it; and several of the dislocations are good copper lodes.

It is not unlikely that the slates and grits rise in Cwm-Dwyfor, where, at the upper end of the valley, they may be seen bending in a wavy dome-like curve, but whether or not they actually belong to the same beds as the gritty strata of the valley of Nant-y-llef, or are accidental in a part of the overlying Bala slates I am unable to determine.

Fig. 58.

The overlying slate of fig. 58 is here so much cleaved that but for the grits the stratification would be undistinguishable. Beyond the point of outcrop the grit slopes southward towards the bottom of the higher valley, but beyond the junction of the brooks it is probably covered up by overlying slates and perhaps cut off by the fault that passes down the valley to Criccieth.

In 1875 I re-examined this difficult ground in company with Mr. David Homfray. We then observed that the grits in the valley of Nant-y-llef are very quartzose and in fact become in part genuine quartzites. The slate overlying them is darkish blue, in this respect resembling the slates that overlie the Lingula grits of Elidyr-fawr and Nant Francon. The slate below them is of a pale grey colour which when split in the lines of bedding show ferruginous stains like the Tremadoc slates of Tremadoc, and Mr. Homfray was decidedly of opinion that they are the actual equivalents of these strata. If this be so then the overlying grit may be the representative of the Arenig or Garth grit which lies at the base of the Arenig series, though lithologically it more resembles the grit of Elidyr-fawr. No fossils though searched for were found in the rocks, and in the centre of the faulted anticlinal at the point marked * in fig. 57, no certain Lingula flags appeared. In the absence of fossils, therefore, the precise age of these strata may still be debated, though I incline to bow to the opinion of a judge so competent as Mr. Homfray.

Llwyd-mawr, Moel Hebog, &c.—In the long valley that stretches between Cwm-Dwyfor and Brynkir bands of grit again appear on the west side of the valley between Braich-y-dinas and Plas-y-pennant, and conglomerate occurs on the hills opposite Brynkir. All these are overlaid and underlaid by dark blue slate, and they are considerably faulted, the cracks sometimes containing a little copper ore and much iron pyrites. The whole dips westward at angles ranging from 20° to 65° towards the felspathic porphyry of Llwyd-mawr, Fig. 59. Though no Tremadoc slates were identified beneath these grits, it is

possible that the underlying blue slate may belong to that part of the series in which the grit represents the Arenig grit of Criccieth and Garth. The cleavage all along this side of the valley dips a few degrees north of west, at angles from 65° to 85°, and sometimes it is vertical, and a slate quarry is worked in them between Dolbenmaen and Llanfihangel-y-pennant. The whole of the blue slaty rocks clearly dip westward under the great mass of felspathic porphyry of Llwyd Mawr, and on the opposite side of the valley the slaty beds, though much obscured by drift, yet as a mass dip distinctly under the felspathic rock that forms the base of Moel Hebog. The rocks, in fact, between Llwyd-mawr and the west side of Moel Hebog form a faulted anticlinal curve about 2 miles in width, and the igneous rocks that cap the slates on either side are equivalents (fig. 59). On the top of the slates fossiliferous sandy Bala beds are found that immediately underlie the porphyry of Moel Hebog, but between these rocks and the river there seems to be no strata so low as the Tremadoc beds, and it is not till we reach the country between Brynkir, Ynys-cynhairn, and Tremadoc that the Tremadoc slates and Lingula beds distinctly crop out in a broad curve, dipping west, north, and north-east, the details of which have been already given in Chapter 12.

Between Criccieth and Nant-y-llef there occurs the vast igneous mass of Llwyd-mawr, already alluded to, forming a wild mountain tract, about 7 miles in length, by about 3 in breadth. Its surface is rough, broken, and strewn with great blocks of porphyry, and its north-western edge is intersected by the sombre *cirques* of Cwm-silen and Cwm-dulyn, the sides of which are high and precipitous and pass down to the old glacier-scooped lakes at their base. The rock consists of a compact felspathic porphyry, blue in its fresh fracture, weathering pale yellow or white, sometimes wavy or "slaggy" in structure, and generally similar to the solid mass of felspathic porphyry that underlies the ashes of Snowdon and Moel Hebog. Mr. Selwyn, who mapped the ground round Moel Hebog and Llwyd-mawr, first proved that all this broad igneous tract forms but an outlying portion of the rocks of Moel Hebog and Snowdon (fig. 59), and, indeed, generally of the great upper lava sheets, that even in their denuded fragmentary condition extend from Carnedd Llewelyn above Nant Francon almost to the north shore of Cardigan Bay.

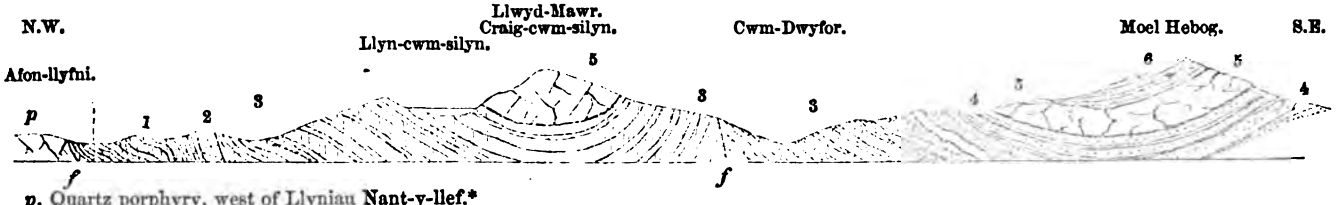
The western boundary of the Llwyd-mawr porphyry between Ynys-ddu and Pant-glas is entirely obscured by glacial drift, and it is possible that a concealed fault runs somewhere along this line, throwing the porphyry down against the slaty rocks on the west. The rest of this line by Llyn-cwm-dulyn and Llyniau-cwm-silyn is well defined, the junction of slate and porphyry being almost visible on the cliffs above the lakes, where beds of altered porcelanic slate dip under it at high angles. Seen from the rocky pass of Cwm Trysgyl on the north flank of Moel Hebog, in a favourable light, an experienced eye can easily detect on the cliffs the general dip of the slaty beds of Mynydd-Tal-y-mignedd beneath the porphyry north of the Carn above Craig-cwm-silyn. The structure of the country will be easily understood by reference to the following section from Moel Hebog across Craig-cwm-silyn to the ground west of Llyniau Lant-y-llef. It includes all the rocks from the quartz porphyry* and Cambrian strata north of Llanllyfni to the ashy equivalent of the Bala limestone that forms the summit of Moel Hebog.

A glance at the map will show that the supposed Lingula flags (fig. 59) north-west of Craig-cwm-silyn are continuous in the line of strike with those of the Pass of Llanberis. The whole of these beds have a tendency here and there to become sandy and ferruginous, thus resembling the Lingula flags of Ffestiniog and Dolgelli. The grits No. 2 south-west of Llyniau Nant-y-llef rest directly on Cambrian slates, but further west the boundary line is much obscured by deep glacial drift. There is, however, little doubt that it passes out to sea about half a mile north of Clynnog-fawr, near Ty-coch. The reasons for this conclusion are, that on the north side of Mynydd Llanllyfni at Llwyd-coed there occurs the most southerly quarry of purple slate in the district (map 75 N.W.), and between this point and Fridd-bach, when not obscured by drift there are indications of purple slates on the north side of the line, and dark blue slate on the south.

* A fuller description of the porphyry (*p*) and of the Cambrian strata is given in pp. 173–178, but in the meantime it may be stated that on the south and west, when not faulted against the porphyry, the Cambrian rocks are often so excessively altered that it is difficult to separate them from the porphyritic mass itself.

Fig. 59.

SECTION FROM THE QUARTZ-PORPHYRY NEAR LLYNIAU NANT-Y-LLEF, ACROSS LLWYD-MAWR, TO MOEL HEBOG.



p. Quartz porphyry, west of Llyniau Nant-y-llef.*
1. Cambrian purple slaty rocks.
2. Probably Cambrian grit.
3. Blue slaty rocks, probably Lingula flags adjoining 2 and in the higher part of the Caradoc or Bala series.
4. Fossiliferous grits, equivalent to those under the Snowdon porphyry.
5. Felspathic porphyry of Craig-cwyn-silyn Llwyd-mawr, equivalent to that of Snowdon, Moel Hebog, Y-Glyder-fawr, &c.
6. Calcareous ashes and conglomerates, equivalent to those of the peak of Snowdon, Dolwyddelan, &c., and on the horizon of the Bala limestone.
f. Faults.

* *See* note on p. 169.

West of Fridd-bach no purple slate is seen, and it is probable that it is cut out by a fault which throws the Silurian strata against a low part of the Cambrian grits and conglomerates similar to those that occur at Glynllifon and Llandwrog.

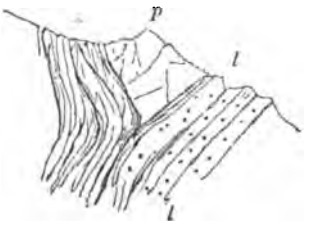
Intrusive Rocks.—The intrusive rocks associated with the Silurian strata described in this chapter are as follows, beginning from the south. There are several patches of greenstone in the valley north of Llanfihangel-y-Pennant, and others in Cwm-y-ffynnon. One of these, Craig-isallt, close to Llanfihangel-y-Pennant, runs across part of the valley in the form of a great bar, and makes a striking feature in the scenery. It consists of a kind of coarse greenstone (diorite) in which the constituents are about two thirds felspar and one third grey and dark green or black hornblende, and the whole somewhat resembles the large mass immediately south-west of Dolgelli. A similar mass lies east of Hafod Caregog. The peak of Y-Garn* consists of an igneous rock similar to that of Mynydd-mawr, and the slates on its western side are seen to dip beneath it. The long strip that runs from the north cliff of Y-Garn towards Llyn Cwellyn is hornblendic greenstone, and other spots of similar rocks lie on and near Mynydd-tal-y-mignedd.

The mass of Mynydd-mawr is one of the most beautiful rocks of this country, consisting of a felspathic base, when slightly weathered of a pale cream colour, in which small specks of horneblende are scattered, and very rarely minute granular crystals of quartz. If deeply quarried the colour of the base would be blue. The specks of hornblende render it unlike any of the great interbedded felspathic lavas which form so much of Snowdon and Moel Hebog. In the form of a great boss it rises through the slate which may be seen here and there in a porcelanised condition on its margin, (fig. 58). An instance occurs on the slope towards Nant-y-llef where the igneous rock abuts on vertical planes which probably are lines of bedding, for, as in the case of the altered slate in contact with greenstone between Dolwyddelan and Ffestiniog, it is unlikely that at Mynydd-mawr the porcelanised slate should have been cleaved after undergoing this species of alteration. The absolute junction is obscure at the base of the north cliff, but near it blue slate and grey arenaceous beds dip towards the tall cliff of Craig-cwm-bychan and Cwm-du, where the rock is largely jointed and somewhat columnar. On the south of the mountain great banks of shingle lie along the steep slope at the base of Craig-y-bera, concealing the absolute boundary, which nevertheless may be approximately inferred.

Nearly opposite the village of Llanberis three greenstone dykes pierce the slate on the hills between Llechog and Y-Tryfan, occasionally breaking a little athwart the slate. (Pl. 28, section 3, and 6-inch sheet No. 28, line 2.) They are distinctly visible from the bottom of the Pass. The eastern dyke splits into two as it rises to the summit of the ridge, while the western dyke thins away at a lower level. Another broad well crystallised dyke cuts the slaty rocks at Ty'n-y-ffynnon on the opposite side of the valley, and three others nearly in the same beds crop out near the summits of the ridge of Moel-y-cynghorion and Moel-goch on their northern slopes, between Llyn Cwellyn and Llanberis.

Fig. 60.

Moel-perfedd.



p. Felspathic porphyry.
l. Lingula grits.

* About 2 miles south of Llyn Cwellyn.

On the west side of Nant Francon the igneous mass of Moel-perfedd rests in a singular manner on the Lingula grits of Carnedd-fiiiast. The base of the rock is felspathic and very sparingly speckled with hornblende. It is intrusive, and alters the rocks with which it is in contact, but instead of rising from below like a dyke or boss, it lies on the summit of the sharp ridge in the form of a large wedge, tapering downwards, fig. 60, p. 171.

It is not easy to account for the occurrence or a rock of this kind in such a position. It does not rise from below through a neck, but possibly before the rocks were thrown into their present inclined position it may have been injected among them in connexion with some larger mass, the continuation having been removed by denudation.

A similar rock intruded in Nant-ffrancon among strata on a higher horizon forms the craggy hill between Blaen-y-Nant and Bwlch-y-Cywion. It resembles some of the granitic rocks in which free silica has not been fairly developed, and in the cliffs above the road and on the heights near Bwlch-y-Cywion small veins have been injected from the main mass among the slates, which at the junction are altered into porcelanite. The layers of slate look wavy at the junction, and quartz veins (not foliated) branch among them just as they often do at the ends of branching veins of granite. The same kind of phenomena are observable about 4 miles further north in the greenstone west of the peak of Yr-Elen. This rock sometimes approaches syenite in its structure, and on the south side of Cwm-Gaseg sends veins into the slate, which in its neighbourhood has a baked aspect, and is spotted like "snake-stone," an appearance common in slates in contact with intrusive masses. On the east side of the greenstone the slate of Yr-Elen and Cwm-gaseg dips towards it at angles varying from 15° to 25°, and on the opposite side the same beds dip 10° S. of E. about 5°. The cleavage is vertical, and its strike in general coincides with that of the bedding. Beyond this is the great intrusive felspathic and occasionally hornblendic mass of Y-Foel-frâs.

CHAPTER XXII.

The Cambrian Rocks of Caernarvonshire. Llanberis, Llyniau Nant-y-llef, &c.

General Description.—It has been already shown that the Cambrian rocks of Merionethshire and Caernarvonshire form the opposite and lowest beds of a great synclinal curve, the upper strata of which are Lower Silurian. Before entering on details I shall describe the general arrangement of the Cambrian strata, near the Menai Straits, between Aber on the north and the neighbourhood of Clynnog-fawr on the south.

On the south the boundary of Cambrian rocks and Lingula flags runs east from Caernarvon Bay to Mynydd Llanllyfni, from whence it strikes north-east through the lower lake of Nant-y-llef, and passes by Bettws Garmon and Dinas to Llyn Padarn, near Llanberis. Here the boundary line bends south-easterly, and, interrupted by several faults, the uppermost Cambrian rocks form the hills on either side of Llyn Peris. From thence the same strata strike north-easterly along the ridge of Elidyr-fach and Bronllwyd to Nant Francon, overlooked all the way by the sharp ridge of the Lingula grits of Elidyr-fawr. In Nant Francon the line crosses the Holyhead road (about 220 yards below the 31st milestone), and interrupted by a north-east fault

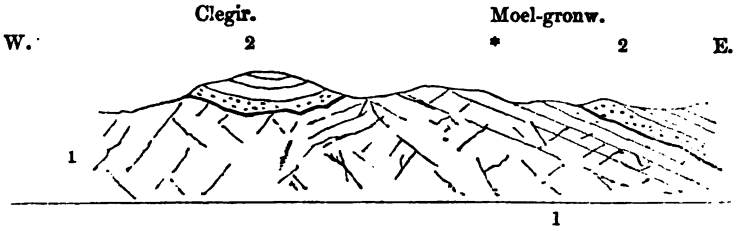
stretches towards Aber, about 2 miles from which the rocks roll over to the west in a broken anticlinal curve which is cut off on its western slope by the great fault that runs south-west from Aber to Dinlle, on the coast of Caernarvon Bay. This fault bounds the Cambrian rocks of Llanberis for about 14 miles, throwing down Silurian slaty shales on the north-west against a low part of these Cambrian strata. From beneath them the Cambrian beds again crop out to the north-west, between Bangor and Llanddeiniolen. Both areas include large masses of quartz porphyry and other crystalline rocks.

Between the quartz porphyry and the Lingula flags of Llyn Peris the whole of the Cambrian rocks, in spite of certain sharp contortions, have an average south-easterly dip. In some degree they differ lithologically from the rocks of Merionethshire, for whereas the latter are chiefly formed of grits, in Caernarvonshire great and valuable beds of slate are interstratified with grit and conglomerate. The cleavage strikes north-easterly with the strike of the beds, and is but little affected by minor contortions, being either vertical or dipping at very high angles south-easterly, in the direction of the average dip of the rocks of the country.

The best sections are in the Passes of Llanberis and Nant Francon, where the succession of the strata, as a whole, is as follows:—The highest beds consist of about 1,300 feet of green, greenish grey, and occasionally of purple hard grits, generally thick-bedded, and formed of grains of quartz often but little waterworn, intermingled with felspar grains in smaller proportion. (Section No. 3, pl. 28, and figs. 69, 70, and 71; also 1-inch map 78 S.E., and 6-inch section, sheet No. 28.) A little copper pyrites has been occasionally worked in it near Llyn Peris. Beneath the grits rise the bluish purple and purple slates of the larger slates quarries of Penrhyn and Llanberis, and below these are other thinner bands of slate, grit, and conglomerate, the lowest of which, by Llyn Padarn and elsewhere, *passes by insensible gradations into* the great mass of quartz-porphyry that for 13 miles strikes along the midst of the Cambrian strata, between Llanllyfni and where St. Ann's chapel, now buried beneath slate quarry rubbish, once stood near the river Ogwen. So closely does the matrix of the altered rock resemble the adjoining typical porphyry in colour, texture, and even in porphyritic character, and by such insensible gradations do they melt into each other, that the suspicion or rather the conviction constantly recurs to the mind that the solid porphyry itself is nothing but the result of the alteration of the stratified masses carried a stage further than the state of porcellanite into the condition of that kind of absolute fusion that in many other regions seems to have resulted in the formation of granites, syenites, and other rocks, commonly called intrusive. This conclusion is further aided by the capricious variation in thickness of the strata adjoining the porphyry, as, for instance, in the case of the thin conglomerates of Llyn Padarn and Clegyr, which are the equivalents of the neighbouring far thicker beds around Dinas Mawr, a little north-west of the lake. This I can

only account for by the supposition that these beds have, as it were, been partly *eaten into* by heat and themselves converted into porphyry. Further, the porphyry itself has in places a bedded appearance, especially on Moel-gronw, where lines that at a distance look like thick beds are inclined in the direction of the dip of the neighbouring strata.

Fig. 61.



1. Porphyry. 2. Grit, conglomerate, and slate.
* Planes in porphyry on Moel-gronw, dipping in accordance with the dip of the overlying strata.

Such appearances have often been explained (perhaps in some cases justly) by the hypothesis of the formation of planes of cooling, supposed to coincide more or less with the lower surface of the strata that once covered underlying crystalline masses, but in this and many other instances I believe rather that the lines indicate traces of stratification in a rock, the original felspathic and quartzose material of which has been metamorphosed into true porphyry.

Details of the Cambrian Rocks, Llanberis, &c.

I shall now describe the Cambrian strata of Llanberis and the country further south in detail. The minor stratigraphical relations are exceedingly intricate.

On the south side of the lakes, between Y-Tryfan and Dinas, the Snowdon section crosses the Cambrian grits, which lie in the form of faulted anticlinal and synclinal curves (plate 28, No. 3, and 6-inch sections sheet No. 28). One of these curves, if restored, would present a form for the Cambrian strata somewhat like that in the two lowest dotted lines above the actual surface of the ground between Dinas and Llanrug. The faults are clearly connected with the contortion of this piece of country on both sides of the lakes. A sharp curve in the strike has, as it were, been attempted between Llyn Peris and Dinas,—the hard rocks resisted the bend and fractured, and six large faults with repetitions of the grits are the consequence. It is the complication induced by these faults that apparently gives the upper Cambrian grit an undue importance along the southern shores of the lakes. Forming a mass of rugged hills and broken ground they appear far thicker than they actually are, and it requires much dissection of the strata to make out that the crags of Pen-carreg-y-fran, the vertical beds of Derwyn, and the inclined strata of

Ceunant-mawr, are together all represented by the narrow strip of grit that crosses east of the slate quarries from Llyn Peris to Nant Francon.

Below Dolbadarn the grits as it were escape from the fractured country, and curving to the south-west by Dinas they gradually thin away towards Bettws Garmon,* where they thin out and disappear.

North-west of Dinas the section of the Cambrian rocks is simpler than on the opposite side of the lakes, though at first the contrary might be supposed. The following is the descending order of the strata, as shown on the section. (No. 3, pl. 28, and 6-inch sections, sheet 28, line 1.) Dipping conformably from 30° to 45° below the Lingula flags No. 6, the upper grits of Dinas (No. 5) are about 1,100 feet thick, and rest on beds of purple and bluish purple slate, No. 4, about 400 feet in thickness, which undulate across the country with a western outcrop, and occupy a space from a quarter to three-eighths of a mile in width. They have been quarried for slate, and it is in the equivalents of these beds that the principal works have been opened north of Llyn Peris, and in the Penrhyn slate quarries. In descending order they are succeeded by about 200 feet of grits, No. 3, similar to those of Dinas and Llyn Peris. They commence by the lake at a small promontory, and stretch for nearly 2 miles to the south-west, where they either die away or are lost beneath the glacial drift. From beneath them about 140 feet of slate crops out, No. 2, of a deep purple colour, pitching to the south-east at an average angle of 26°. In this division the principal slate quarries lie on the south-west side of the lake, although the beds are not more than half the thickness of the slaty strata that lie above the last-mentioned grits. Owing to the lowness of the ground, which is somewhat unfavourable for getting easily rid of rubbish, and also to the quality of the slate, due in part to numerous joints which cut up the body of the rock into fragments. these quarries have generally never been so successfully worked as those on the opposite side of the lakes, even although the cleavage is sufficiently close and fine, and either vertical or dipping at angles approaching 90° to the north-west.

Underneath the beds last described there lies a mass of conglomerate and grit, No. 1, already alluded to (p. 173), the absolute thickness of which varies, owing to its irregular passage into the porphyry that forms its western boundary.

On the western bank of Llyn Padarn, near the Glyn slate quarries, the base of the conglomerate is highly felspathic and sometimes crystalline, enclosing pebbles of felspathic trap, quartz-porphyry, quartz, quartz rock, purple and black slate, and red and green jasper. The whole mass is altered, the alteration increasing as it approaches the undoubted porphyry, and it is easy to note, first, the disappearance of the ordinary sandy granular structure in the matrix that surrounds the pebbles of the conglo-

* At the south-west corner of the sheet in the valley of Llyn Cwellyn.

merate, and its gradual assumption of a porphyritic character with small crystals of felspar, while the enclosed pebbles still retain their distinctive forms; and again, approaching the recognized porphyry, the hard outlines of the pebbles in the conglomerate gradually become more and more indistinct, till at length they become quite indistinguishable in the general fusion of the rock: and the view, that the porphyry is not an intrusive mass in the ordinary sense—breaking through and tilting the strata—is aided by the fact that here it is impossible to define any line of demarcation between conglomerate and porphyry, for, among other reasons, though the strata as a whole undulate to the south-east at low angles on the south bank of Llyn Padarn, yet the last dip is *towards* the porphyry, evidently without a fault. Aided by heat and moisture, the alkali in the felspathic pebbles and in grains of felspar in the sandy matrix, would aid in this alteration. There is nothing in the appearance of the porphyry contrary to this idea, for its general character is that of a rock with an amorphous grey felspathic base (like that of the altered rocks adjoining), containing small scattered crystals of quartz, which are often somewhat *granular*, sometimes hexagonal, and sometimes they seem to be four-sided prisms, as if pseudomorphous. Like the altered strata it also contains small distinct crystals of glassy felspar. On the whole the rock tends to confirm the impression made on me by the rocks of Moel-gronw on the opposite side of the lake, that the porphyry itself may be nothing else than Cambrian rocks that have undergone the extreme of alteration (fig. 61, p. 174).

From Llyn Padarn the conglomerate* stretches to the south-west separating the purple slate and porphyry. It crosses the valley of Llyn Cwellyn about half a mile below Bettws Garmon, and on the broken ground on the south-west side of this valley the same general phenomena of alteration occur that are so well seen on the banks of Llyn Padarn. Further south the conglomerate forms the highest points of Moel-y-Tryfan and Mynydd-y-Cilgwyn (75° N.W.), where it is partly metamorphosed into a sort of talcose schist and conglomerate. Beyond this it has been either completely obliterated by alteration and fusion, or curving round to the east near the crest of the hill is cut off by a fault that throws the superincumbent purple slate directly against the porphyry.

It will be gathered from part of the foregoing remarks that the upper Cambrian grits of Llyn Peris and Dinas die off to the south-west at Bettws Garmon, the middle grits at Ceunant on the moor, and the lower conglomerates disappear at Mynydd-y-Cilgwyn, but the purple slates that are interstratified with these follow an unbroken course to the neighbourhood of the turnpike road near Llanllyfni. South-west of Bettws Garmon they rise directly from under the Lingula beds, unless possibly undetected thin Menevian beds may be there. By the lower lake of Nant-y-llef they are largely and successfully quarried close to the quartz porphyry

* Opposite the letters "lyn" in Map 78 S.

which rises on the west of the lowest quarry like a great wall in direct juxta-position with slate. The unporcelanized condition of the slate where it touches the porphyry, together with the marked occurrence of slickensides there, seem to indicate a fault, while in places the quartz porphyry itself still seems to show what may possibly be traces of an original stratification that has almost been obliterated by some kind of metamorphic action. South of Llanllyfni the strike of the Cambrian rocks changes to W.N.W., and the purple slate does not occur south or south-west of Mynydd-Llanllyfni and Ty Coch, near Clynnog-fawr on the coast. The drift-covered district further south is composed of dark and ferruginous Silurian slaty shales and grey sandstones. The point furthest south where purple slate has been observed is at Llwyd Coed, about a mile south of Llanllyfni, and to the west of the last-named places the ground is so obscure that the reason of the disappearance of the slate in that direction is uncertain. The fault alluded to above, which throws the slate against the porphyry at Nantlle, is probably continued along the boundary of the trap as far as Llanllyfni, and west of that village perhaps throws the slates down against the low Cambrian grits and conglomerates that form the western and southern boundary of the porphyry, from Afon Rothell below Llyn Padarn to Llanllyfni.

The boundaries above described are, however, by no means definite, for, being on both sides much obscured by drift, they are in places mere approximations, and the absolute continuity of the porphyry itself is deduced from imperfect but probably safe data. Thus, though the underlying rock be unseen, the shape of the ground aids the experienced eye, and the drift itself often lends a hint of the nature of the rock immediately beneath, from which its material is frequently largely derived. A debris of large angular fragments also often tells of the close neighbourhood of the parent rock, and altered rocks lying in the assumed line of the margin of the porphyry also assist. Further, wherever the drift has been removed in the area mapped as porphyry there it has been found. Some of these places may be named for the use of those who care about details.

On the rail at Afon-llyfni,* and from thence to Mynydd-y-Cilgwyn, the slopes are rough and rocky, and the quartz porphyry is everywhere visible. Next it is seen in the brook at Melin Forgan, and at Ty-newydd, Moel, Caerwen, and several places on the river Gorfai, after which, except at one place on its western edge, north-east of the Caernarvon and Beddgelert road, it is entirely obscured by drift, till it again stands boldly out on the rocky ground that overlooks Llyn Padarn and the river Rothell. On the opposite side of the lake it forms the crags of Clegir and Moel-gronw, and traces of the same kind of rock occur as far north as Craig-y-Nyth, beyond which, to where St. Ann's chapel once stood (now buried beneath the rubbish of the Penrhyn slate quarries), a broad level tract of country is entirely obscured by turbary

* Map 75 N.W.

and deep glacial drift, largely charged with miscellaneous boulders derived from the neighbouring mountains. In the year 1850, however, a shaft was sunk by Colonel Pennant between St. Ann's chapel and the Penrhyn slate quarries, and there the porphyry was found, at a point where it might be expected if it were continuous so far north-west, for there seems no good reason, except the covering of drift, why it should suddenly disappear on the hills above Llyn Padarn. That it does not cross the river Ogwen is certain, but it is probably close beneath the thick beds of slate that immediately underlie the uppermost Cambrian grits in the anticlinal curve between Bethesda and the bridge over the Ogwen.

Such is the general relation of the porphyry to the stratified Cambrian rocks, and I shall now proceed with a more minute description of the latter on the north side of the lakes of Llanberis.

On the north side of Llyn Padarn there are certain bands of grit, shown in the following diagram, some of which do not appear on the south.

Fig. 62.

SECTION BY THE RAILWAY, LLYN PADARN, BETWEEN THE PORPHYRY AND YR-ALLT-WEN.

N.W. S.E.

P. Porphyry. *g*. Greenstone dykes.
1 to 10. Cambrian conglomerates, grits, and slates.

P represents the porphyry, which bears the same relation to the neighbouring conglomerate that it does on the opposite side of the lake, and the phenomena are so instructive that I give a second description, even though almost the same in both places. The bluish grey felspathic base of the porphyry encloses small hexagonal and four-sided crystals of felspar. Grains or rather imperfect crystals of very clear quartz are also dispersed in the base, the result apparently of attempts at crystallization, or possibly in some cases relics of a rock of which the porphyry is the thoroughly altered representative. As on the opposite shore, there is a gradual passage from porphyry to the conglomerate and grit No. 1. The latter, near its margin, has often a grey felspathic base similar to that of the adjoining porphyry. Felspar crystals and granular or more perfect quartz crystals also occur in it, decreasing in quantity with increased distance from the porphyry and diminished alteration of the rock.

A little farther from the porphyry, the base includes traces of quartzose and felspathic pebbles, the indistinct outlines of which are seemingly due to the partial fusion of their edges into the once-melted or softened enveloping matrix. Further off, the pebbles become more distinct, the granular quartz crystals still continuing, and by degrees the whole rock passes into a comparatively unaltered conglomerate. No. 2 is purple slate lying in a

trough, and the grits and conglomerates 1′ that rise from beneath are identical with those of No. 1, but, though so near, somewhat thicker, thus affording additional evidence that on the west side of the synclinal bend a part of these beds has been melted and used in the formation of the porphyry. The rocks marked 1′ are also altered, even though, at the surface, 600 or 700 feet distant from the porphyry, still further evincing, in my opinion, not the mere intrusion of an igneous mass below which effected the special alteration of this conglomerate, but rather, that here, the rocks on this horizon, before the conclusion of the Lower Silurian period, were partly melted and partly altered deep beneath the surface, and thus it happens that, exposed by denudation, melted and altered rocks alike rise and fall with the anticlinal and synclinal curves that affect the rocks of the country; the porphyry itself having nothing to do with the production of these disturbances.

Part of the conglomerate 1′ (Fig. 63) consists of slaty pebbles in a slaty matrix, the whole being affected by slaty cleavage, remarkable on account of the pebbles being elongated in the direction of the cleavage lines, and obliquely to the planes of bedding,

Fig. 63.

PEBBLES ELONGATED IN THE LINES OF CLEAVAGE.

in accordance with which under ordinary circumstances the flat sides of the pebbles would naturally lie; this arrangement being due to intense pressure, which, in all cases of slaty cleavage, caused the particles composing the rock to arrange themselves approximately at right angles to the direction of the compressing force. In this case these effects are *visible*, the pebbles having been both lengthened and flattened by the same pressure.*

The higher part of 1′ consists of green and purple grits underlying green and purple banded slates 2′ (=2) overlaid by a thick hard grit marked 3, which thins rapidly out on the slopes above or else passes into slate by change of material. By the lake it is overlaid by other bands of green and purple banded slate, alternating with grits, marked 4 and 5. Resting on these are purple slates, 6, underlying a band of thick-bedded grit, No. 7, which crops out on the woody crags at the western end of Yr-Allt-wen.

By reference to the 1-inch map† it will be seen that the Cambrian beds above described first strike northerly, and then curving

* I first observed this fact in 1848, and in 1849 pointed it out to Sir Henry de la Beche and the late Professor E. Forbes, but for a time they would not admit what seemed to them so novel an idea. It was with much satisfaction that I afterwards saw a similar case described by Mr. Daniel Sharp, in his memoir "On Slaty Cleavage," published in 1848. I did not, however, till the publication of Mr. Sorby's memoirs, understand the cause of this phenomenon, so well established by his writings and those of Dr. Tyndall.

† 78 S.E.

east and south-east, abut on a fault that runs north from Llyn Padarn. The uppermost grit, No. 7 of the diagram 62, is overlaid by a great mass of purplish blue slate, No. 8, which, highly contorted and intersected by thre e principal north and south faults, forms nearly the whole of Yr-Allt-wen, extending east as far as a marked band of grit that strikes northward from Llyn-Peris a little east of Pont-y-Bala. This band at Llyn Peris dips west beneath the "blue slate" which is thus, but for small interruptions caused by faults, entirely underlaid and enclosed at the surface by the grit on the east, north, and west. Above the "blue slate" there is by Llyn Padarn a thin band of grit, No. 9 of the diagram. It curves contortedly up the south slope of Yr-Allt-wen, and resting on it are purple slates, No. 10.

The last and uppermost three divisions, all along the shore of Llyn Padarn, are mere denuded repetitions of beds further east; for the "blue slate" of Yr-Allt-wen is the equivalent of that of the great Dinorwic quarries, on the steep slopes above Llyn Peris, and the overlying band of contorted grit by Llyn Padarn represents the thin band that at Llyn Peris lies close above the blue slate. Further the uppermost purple slate 10 on the shore of Llyn Padarn is the precise equivalent of the highest Cambrian purple slate of the district, viz., those that lie between the thin grit band on the map and the green slate that immediately underlies the 1,300 feet of grit that forms the ridge of Elidyr-fach. Such is the section along the north shore of Llyn Padarn, an analysis of which unexpectedly shows that all the Cambrian beds of the Llanberis district are present at Llyn Padarn, with the exception of the uppermost green slate and the Cambrian grits of Elidyr-fach that immediately underlie the Lingula beds.

I shall now explain the structure of the country a little further north.

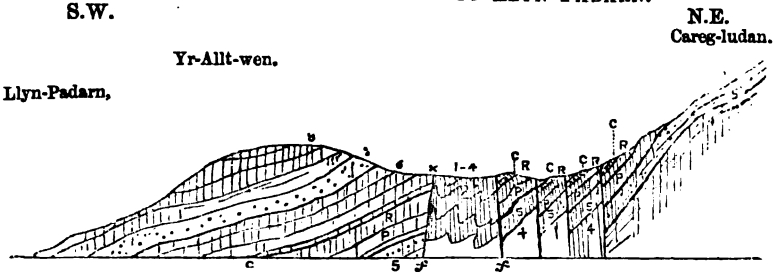
Above the old tramway, half a mile west of Elidyr-fach, there is a triangular tract of grit (No. 5, fig. 64).* An old road, once ran through it, and nearly in the midst once stood the cottage of Careg-ludan. At one of its southern angles it is faulted against the grit No. 7, that lies beneath the "blue slate" of Yr-Allt-wen. Partly obscured by drift this mass of grit cases the south side of the hill in the manner shown in fig. 63, and where unfaultted it dips on the south *beneath* the purple slates that in a crescent form lie immediately north of Yr-Allt-wen, and end in the middle of the little bay about the middle of Llyn Padarn. The purple slates immediately south-east of the Careg-ludan grit are the same. They occupy a triangular piece of ground about a mile long and half a mile wide, that lies between the grits and two faults that strike from Llyn Peris towards Marchlyn-bach, and where unfaulted, resting on the Careg-ludan grit they underlie the narrow strip that runs along the eastern limb of the letter *n* on the map. A south-west section from Careg-ludan to Llyn

* The equivalent No. 5 in Fig. 61. *See also* 1-inch Map, 78 S.E.

Padarn gives the following general arrangement of the strata. The numbers correspond to those in diagram No. 62.*

Fig. 64.

SECTION FROM CAREG-LUDAN TO LLYN PADARN.



No. 5 represents the grit of Careg-ludan, and 6 the purple slaty series below the grit 7, which grit underlies the "blue slate," No. 8, of Yr-Allt-wen. The fine dark purple slate quarries of Allt-ddu lie in the hollow near the outcrop of No. 5.† The faults marked *f* in the diagram are indicated on the map, but the others nearer Careg-ludan are too small and close to be noticed on the 1-inch scale. They are all easterly downthrows, and in the hollow repeat the lower part of the strata No. 6 three times. These rocks contain certain bands by means of which the faults were detected by the late Mr. Griffith Ellis in ground otherwise very obscure. The highest beds, immediately below grit 7, are of purple slate, beneath which is a thin band of calcareous sandstone marked C, overlying a red slate marked R, which rests on a purplish blue slate P, lying on grit No. 5, West of the ground affected by the minor faults there are two large parallel faults marked *f*, running north from Llyn Padarn, and crushed between them lies a narrow strip of purple and green slaty rocks running right across Yr-Allt-wen in an unexpected position, for these slates are the equivalents of the beds that immediately rest on the altered conglomerate that adjoins the porphyry (1 to 4, fig. 62). The purple slates (6) abut on the most westerly of these faults, as shown in fig. 64 at ×.

North of Careg-ludan, on the moor (Waun-gynfil) the rocks are almost entirely obscured by drift, but several indications show it to be probable that the grits strike across the moor in narrow bands to the Penrhyn slate quarries, where, on the west side of the quarry they appear in order similar to that above the lakes, but less disturbed.

I have thus far explained the Cambrian section in ascending order, because the superposition of all the lower strata near the porphyry is easily seen by help of the railway cutting. The

* The horizontal scale is 4 inches to a mile, the vertical merely sketched.

† Two quarries were worked in equivalent beds between grits 5 and 7 west of Allt-wen.

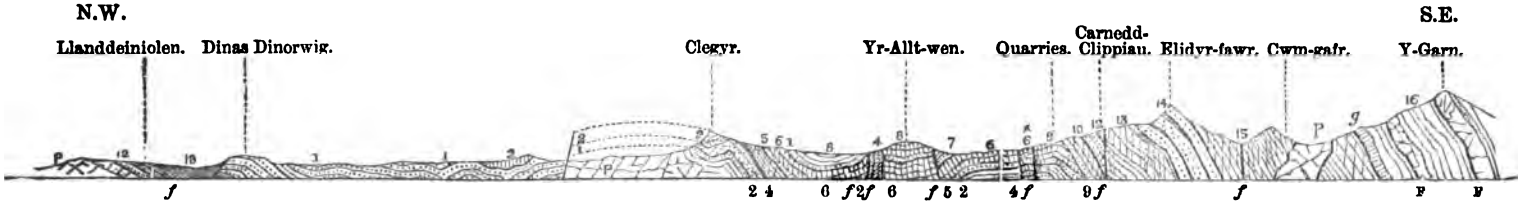
middle ground is difficult, but clear when attentively studied; and the order of the upper beds, close by the thick grits of Elidyr-fach, becomes plain when carefully unravelled. That the mutual relations of the whole of the rocks of the district between Llanberis and Nant Francon may be thoroughly understood, I shall now describe the beds in descending order, beginning with the overlying Silurian strata on an horizon a little below the equivalents of the Bala limestone. The section, fig. 65, passes from the peak of Y-Garn to the Bangor and Caernarvon porphyry, near Llanddeiniolen, in a line N. 15° W. The numbers correspond with those in figs. 62 and 64.

In descending order, No. 16 represents Bala grits and slates, highly fossiliferous, interbeded with two bands of felstone marked F, the highest of which it has been shown is the northern continuation of the lower part of the great mass of felspathic porphyry that forms the base of Snowdon (pl. 28, Nos. 2 and 3, and figs. 38 and 39). *g* is greenstone intruded between the lines of bedding, and to the west of the intrusive porphyry of Cwm-gafr (*F*) are beds of highly cleaved slate, No. 15, dark in colour in the upper strata, but light coloured as we approach the fault. As already stated unless the lower part of this slaty series represent the Tremadoc slate, which is yet unproved, then it is possible that it may represent the Arenig slates. If they be the equivalents of the Tremadoc slates, the Arenig beds may be looked for higher in the series, unless they are cut out by the fault marked in section 65 east of Elidyr-fawr, which under these circumstances would give an unusual thickness to the Tremadoc slates. However this may be, the Lingula beds of Elidyr-fawr (14) rise from beneath them, below which are the slaty Lingula flags equivalent to those in which *Lingulella Davisii* and *Olenus macrurus* were found in this neighbourhood between Marchlyn-mawr and Marchlyn-bach. The ferruginous slaty beds of the Lingula flags (13) are in this section shown to be faulted against part of the Cambrian grits of Elidyr-fach (12), and immediately underneath the latter is a band about 20 or 30 feet thick of *green slate*, which in this area is very constant, being invariably found under these grits in all the Caernarvonshire sections. It is underlaid by the uppermost bands of purple slate, No. 10, and these are separated from the "*blue slate*" (8) (purplish blue) by a band of grit from 4 to 6 feet thick, No. 9, which is found precisely in the same position on the eastern side of the Penrhyn slate quarries in Nant Francon.

The principal quarries at Llanberis are in the "blue slate" on the side of the hill north of Llyn Peris, and these beds are the precise equivalents of the "blue slate" of Yr-Allt-wen, above Llyn Padarn, fig. 64. Its absolute thickness at the quarries in question is not very great, but the same beds (No. 8) being repeated by contortion, and the cleavage cutting through the whole nearly vertically, the body of slate appears to be much larger than it really is to those who are unable to detect faint signs of bedding unobliterated by cleavage. An enlargement of part of

Fig. 65.

SECTION FROM Y-GARN BETWEEN LLANBERIS AND NANT FRANCON TO LLANDDEINIOLEN.



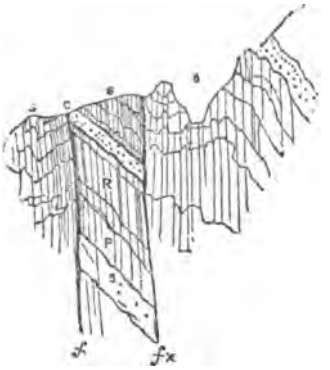
1, 5, 7, 9, 12. Grits. } Cambrian.
2, 4, 6, 8, 10, 11. Slates. }
13. Lingula flags. } Silurian.
14. Lingula grits.
15, 16. Llandeilo and Caradoc or Bala beds. }

F. Felspathic lava beds.
G. Greenstones, intrusive.
P. Porphyries, intrusive.
f. Faults.

fig. 64 below × gave the following details in the Llanberis district in 1855 :—

West of the "blue slate" (8), between two faults close together marked *f*, *f*×, is a long narrow strip of rocks belonging to the series marked No. 6, which are the equivalents of part of the rocks indicated in the detailed section No. 66.

Fig. 66.



8. "Blue slate."
f, *f*+ Faults.
6. Purple slate at the top.
C. A band of calcareous grit.
R. Red slate.
P. Purple slate.
5. Grit, which is the equivalent of those marked 5 in diagrams Nos. 2 and 65.*

Westward of these faults, as shown in fig. 64, the strata marked 6 are repeated. In these beds the Allt-wen quarries are situated, which, as already stated, are the true equivalents of the old quarries above the north shore of Llyn Padarn half way down the lake, and also of the Glyn quarries on the opposite shore. With sundry contortions they dip westward, on the north shore of the lake, and on them rests the band of grit (7) that runs from the western part of Llyn Peris to the north. It is thrown down by a small fault to the east, and, as shown in the section, the same grit must run through the middle of Yr-Allt-wen overlaid by the "blue slate" (8) on the top of the hill. West of this, between two faults that cross the hill from north to south, are purple and banded green slates, marked 2 and 4, equivalent to those that rest on the conglomerates of Clegyr. Between the faults and Clegyr, fig. 65, the "blue slate" (8) and the underlying grit (7) are again rolled in on the surface in a synclinal bend, and westward of these the lower grits, conglomerates, and banded slates, Nos. 1 to 6, crop to the surface in succession. The top of Clegyr consists of slate lying in a trough of highly altered conglomerate, No. 1. The above analysis shows that, as a whole, between the west side of Carnedd-Clippiau and Clegyr the country

* It is the prolongation of these faults on the opposite side of the lake that throws in the strip of Lingula beds between the broken masses of Cambrian grit on Pen-Careg-Fran.

as it now stands lies in the form of faulted anticlinal and synclinal curves. The "blue slate" (No. 8) which crops to the surface from beneath the great mass of the Cambrian grits of Elidyr-fach, rolls over to the westward, and partly undenuded, is caught on the top of Yr-Allt-wen, and rises on the western slope of that hill facing Clegyr, fig. 65.

On the north-west side of the porphyry (P) the Cambrian conglomerate and grit (1) and the lowest slates (2) are again thrown in on this line of section by a fault which passes under the alluvium opposite Cwm-y-glo and is small in amount at that end, but gradually increases on the north-east towards the ground on which St. Ann's chapel stood. The conglomerate is well shown at Llys Dinorwig and on the hill of Dinas Mawr above the railway, and banded coarse slatey beds (2) resting on them may be seen much contorted in the neighbouring railway cutting. They apparently lie in a trough, which widens on the north in the manner shown in the 1-inch map, and they are the equivalents of the lowest slaty beds that encircle the base of Moel-y-ci, three miles to the N.E. The eastern boundary of the trough is certain, but that on the west is much obscured by drift. Beyond it to Dinas Dinorwig* there are thick beds of hard grit and conglomerate (1), much concealed, but the general nature of which is shown on the banks of Afon Rothell, on the slopes of Dinas-mawr and west of Pont Rothell. South-west of the river the country is equally covered, but wherever Cambrian rocks in place rise through the drift they are grits and conglomerates.

Between Dinas Dinorwig and Llanddeiniolen the section (fig. 66) crosses the Aber and Dinlle fault already alluded to (p. 173). It will be more fully described further on (p. 200–204), but in the meanwhile it may be stated that being a very large downthrow on the north-west, its effect here is to throw in black slates (13) against the lowest part of the Cambrian grit of the district, which in fig. 64 is marked dipping S.E. in the hill crowned by the old camp of Dinas Dinorwig. From beneath these Silurian slates the Cambrian grit (12) rises at Llanddeiniolen. This grit is very much altered, and adjoins the crystalline rock (P) that runs from Bangor to Caernarvon. The arrangement of the same sets of strata is also well shown in sections 2 and 3, pl. 28.

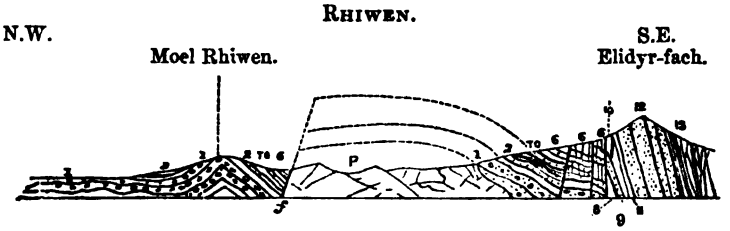
The foregoing description largely applies to the rocks at Llanberis north of the lakes, and as the "blue slate" (8) is there most valuable, it will some day be of importance to know if it is continuous beyond the present Dinorwic quarries towards Marchlyn-bach, on the moor further north. In these quarries, as shown in fig. 65, the lower part of the "blue slate" is not reached being cut out by the fault $f\times$, which is a downthrow on the east; and if that fault be followed in its probable northward continuation, it appears likely that for at least a quarter of a mile the "blue slate" is entirely cut out on the slope of the hill, there being no space for

* Slaty beds appear below the south-east side of Dinas Dinorwig, but they are so poorly shown and so quickly lost under drift that it was impossible to trace them on the map.

it between the fault and the uppermost purple and green slates that immediately underlie the grits of Elidyr-fach. If this be correct, it seems unlikely that the "blue slate" (8) again rises to the surface till we approach Marchlyn-bach, and the following section, drawn north-west from Elidyr-fach, gives the probable arrangement of the strata in descending order, at a point where the "blue slate" is cut out at the surface by a fault.

Fig. 67.

SECTION ACROSS THE CAMBRIAN ROCKS FROM ELIDYR-FACH TO MOEL RHIWEN.



P. Quartz porphyry.
1. Conglomerate.
2. Purple slate.
3. Grit.
4. Purple and green banded slate.
5. Grit.
6. Purple slate.
8. "Blue slate" (bluish purple).
9. Grit.
10. Purple slate.
11. Green slate.
12. Thick grits (1,000 feet or more).
13. Lingula beds.

} Cambrian.

On the south-east we have, first, the base of the Lingula slates, No. 13, overlying the uppermost Cambrian grits (12), which rest on light green slate (11), below which is a purple slate (10) followed by the thin grit band (9), which in the quarries divides the upper purple and "blue slate" (8). Here the "blue slate" is entirely cut out at the surface by the most easterly of three faults, while its probable position underground is represented. Between the faults the lower purple slate (6) forms the surface, and further west the succesion of slates, grits, and conglomerates is continued down to the porphyry marked P. Beyond the porphyry the same slates and grits are repeated on Moel Rhiwen by a fault. They first dip easterly, are not altered, and abut on the porphyry by the increase in this direction of the same fault that in fig. 65 merely throws against it the conglomerate No. 1.

It is at present impossible, without special excavations, to say at what point further north the "blue slate" may again crop out to the surface on its passage to the Penrhyn quarries in Nant Francon, but with the imperfect knowledge that may be gleaned, it seems probable that clear of the faults it may rise to the surface from an eighth to a quarter of a mile S.S.W. of the outlet of Marchlyn-bach, from whence, unless again cut out by drift-concealed faults, it may continue unbroken to the Penrhyn slate quarries.

If this interval be [illegible] about a quarter of a mile N.N.E. of the efflux of Llyn-y-mwn, the arrangements of the rocks generally, and the position of the upper slates in particular, would be nearly as represented in the section that runs from Y-Gyrdan-fawr near Moel-y-Ci to the Llanberis ridge (section 2. pl. 28.).* It must however be remembered that where that section crosses the moor of Tomen-gryll between Llyn-y-mwn and Moel-y-Ci the soil and drift is so deep that for more than two miles the position of the porphyry, slates, and other rocks as laid down, was inferred from evidence obtained further to the north and south. Between the Llanberis grits at Llyn-y-mwn and the base of the Cambrian grits near Moel-y-Ci there can be no hesitation in drawing the rocks as they are shown in the section, but west of that the conglomerate No. 1 of fig. 5 is supposed to be obliterated by excessive alteration. The evidence of this is certainly imperfect, but from symptoms observed between the Penrhyn slate quarries and St. Ann's chapel, it seems to point in that direction.†

In the midst of the tertiary, on the north-west side of the porphyry, a boundary line is drawn, already alluded to as a fault. It runs from Bryn Efail opposite Cwm-y-glo‡ to the now buried St. Ann's chapel,§ and the cross roads near Tan-y-graig,‖ from whence it passes northward on the east of Gyrn to the higher part of Afon-y-garn and into the Aber river, where it probably ends against a north-west fault near Aber. The reasons for considering that the north-west boundary of the Llyn Padarn porphyry is a fault are as follows:—

On the north-west side of the quartz porphyry, near the village of Llanbabo, there are marked on the map four sets of beds of conglomerate and grit, which I have stated are the general equivalents of the four conglomerates and grits that lie on the north shore of Llyn Padarn, between Clegyr and Yr-Allt-wen (fig. 62). Though all dipping easterly, and on opposite sides of the porphyry, the succession of strata near Clegyr and on Moel Rhiwen and Drysgol-fawr is the same. East of the porphyry, on Clegyr, there is a coarse conglomerate at the base, overlaid by purple and green streaked slates interstratified with three bands of grit, fig. 65. West of the porphyry, on Moel Rhiwen (67) and Drysgol-fawr (68), there is precisely the same arrangement of strata, and the beds striking south-west and south, with an easterly dip, must abut on the porphyry towards Llanbabo. But it may be said, why introduce a hypothetical fault, when the porphyry being intrusive may anywhere cut off part of the invaded strata, more especially since, on the opposite side of the lake, porphyry and

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* Six-inch sheets No. 31, line 2, and No. 8, fig. 2. pl. 28.

† *Field geologists* will readily understand how the mind often arrives at probable conclusions difficult or impossible of absolute proof, from a kind of evidence only appreciable by those who have studied and worked out a country in great detail.

‡ Half a mile north-west of the efflux of Llyn Padarn.

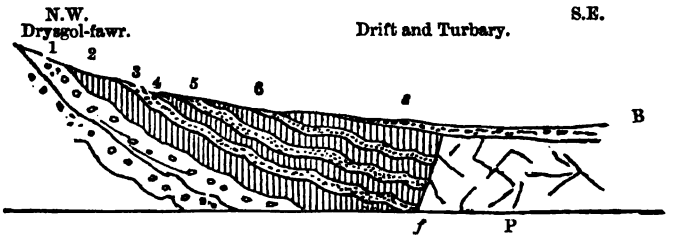
§ At the entrance to Nant Francon.

‖ East of Bethesda.

conglomerate pass into each other insensibly? The reply is, that on the south-east side of the porphyry the grits and slates, No. 1 to 8, dip easterly in such a way that if prolonged (in spite of such minor undulations as that of Clegyr) they would still rise somewhat above the present surface of the trap in the manner indicated by the dotted lines in figs. 65 and 67, and the fact that a set of beds appear dipping *easterly* on the west of the porphyry, the same in number, arrangement, and lithological character as those on the east, affords sufficient evidence that the Rhiwen strata, from 1 to 6 (fig. 67) are the same beds repeated by a fault, which by the side of the river opposite Cwm-y-glo throws the lowest conglomerate at the surface against the porphyry; and this fault increasing to the north-east, the purple and green slates, No. 6, and perhaps part of the overlying "blue slate" below *s*, abut directly against it in the manner shown in the following diagram, at the fault marked *f*.

Fig. 68.

SECTION ACROSS THE CAMBRIAN ROCKS AT DRYSGOL-FAWR.



P. Quartz porphyry.
B. Boulder-drift.
f. Fault.
1 to 6. Purple and green slates and conglomerate and grits.
s. Blue slate below glacial boulder deposits.

West of the porphyry, the same strata strike towards St. Ann's chapel in Nant Francon, and as they dip south-east, and as their precise equivalents in the Penrhyn slate quarries (the porphyry being concealed by drift) also dip in the same direction (fig. 70, p. 192), the fault may be considered certain. Across the river Ogwen, in the same north-east line, the uppermost Cambrian grits (No. 12 of the diagrams) and the Lingula flags are found to be thrown down to the west by a fault of about 2,000 feet, and this concludes the evidence.

Valuable slate beds may perhaps lie under the drift and turbary of the high plateau between Llyn Padarn and Bethesda, but, without sinking, there is no means of determining the precise nature of the beds marked *s* (fig. 68). Probably they are little more than 100 feet thick. Their position proves that the lower beds belong to a high part of the purple strata that underlie the "blue slate," and it seems not unlikely that some of the latter may also lie in the space west of the fault; but whether they occur there or not, the drift is so deep, and on the upper flats the shape of the ground is generally so unfavourable for quarrying,

that, unless they were quarried gradually to the south-west from the slopes above the Ogwen, it seems unlikely they will be turned to use.

The Drysgol-fawr strata (Nos. 2 to 5) are repeated on Moel-y-Ci, rolling over in a gentle anticlinal, and rising in a synclinal curve on the north-west side of the hill, section 2, pl. 28. At its base the lower conglomerates (No. 1) rise to the surface, and continue as far as the Aber and Dinlle fault, along which Lower Silurian strata are thrown down on the north-west against the lowest member of the Cambrian strata in Caernarvonshire, in the manner shown in the above-named section and in fig. 66, and in sections 2 and 3, pl. 28.*

* Also 6-inch sections, sheet 31, line 1, and 1-inch map.

CHAPTER XXIII.

CAMBRIAN ROCKS—*continued.* NANT FRANCON; THE VALLEY OF THE OGWEN.

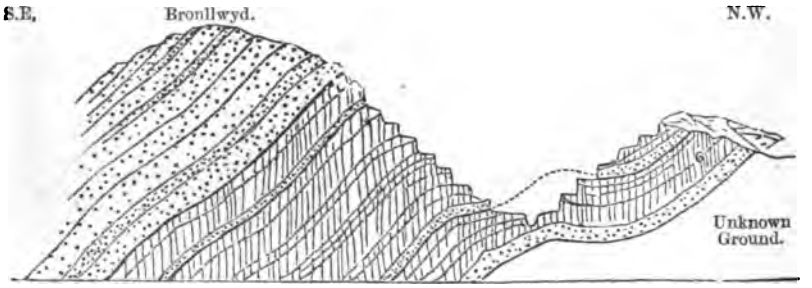
The Cambrian section on the Ogwen between Nant Francon and Bangor is essentially the same as that in the Pass of Llanberis, but simpler, for the strata are less faulted and contorted. The rocks which by the lakes of Llanberis occupy a breadth of 2½ miles, close to the Penrhyn quarries lie in a breadth of little more than half a mile between Bronllwyd and the quartz porphyry (figs. 69 and 70). North of the Ogwen, towards Llanllechid, the structure of the country is even less complicated, for many of the faults that break the strata further south cease at the river, and, the porphyry also being absent, there is an unbroken ascending section from the lower Cambrian conglomerate to the Lingula beds of Moel Faban (fig. 71, p. 193).

The details of the structure of the country are as follows:—

Between Heaterstone* and the Penrhyn quarries deep boulder-drift continues to hide the rocks. The general position of the slate is, however, unmistakeably indicated by the unbroken strike of the grits of Bronllwyd. Looking to the S.W. *up* the Penrhyn slate quarries, the strata lie as they are drawn in the following diagram.†

Fig. 69.

SECTION OF THE PENRHYN SLATE QUARRY.



5, 7, 9, 12, Grits } Cambrian.
6, 8, 10, 11, Slates }

The numbers of the beds correspond with those given in the diagrams of the Llanberis quarries. The grits of Bronllwyd (No. 12) dip nearly east at an angle of about 60°. The usual green slates (No. 11) crop from underneath. These are succeeded by the upper purple slate (No. 10) separated by the thin bed of grit (9) from the "blue slate" (8), the colour of which becomes more purple towards the beds near the bottom of the quarry. Under this is the grit (7) equivalent to the grit that underlies Yr-Allt-wen at Llyn Padarn. Beneath it, in the bottom of the quarry, is the purple slate (6). Part of these strata, including a portion of the "blue slate," bends over to the north-west in an anticlinal curve, and immediately rises in a minor synclinal curve, so that besides forming the greater part of the quarry on the south-east, a part of the "blue slate" also occurs in the terraces on its north-western side. For a space the grit No. 7 is exposed in a curving line in the bottom of the quarry.

* Half way between the Llanberis and Penrhyn quarries.

† The scale not being measured, it must be looked on as a sketch, and not as a true section. It is horizontally about 5 inches to a mile. Since this description was written, the progress of the work has produced a considerable enlargement, and, therefore, some changes in geological details in the quarry. The broad features, are however the same.

Its outcrop and that of the lower slate (No. 6) were hidden by the rubbish of the quarry, when the geological map was made, and which, with the drift and alluvium in the valley, concealed the uprise of the quartz porphyry towards St. Ann's Chapel. It is probable that the lowest green and banded purple slates and conglomerate of the Llanberis section are here cut out by the occurrence of the porphyry passing into a part of the Cambrian series higher than the beds *which pass into it* on the shores of Llyn Padarn. West of the porphyry on the moor the order of the rocks has already been explained (p. 188).

A general section drawn from Cwm-graianog across the slate quarries to the neighbourhood of Llyn Cororion* gives the following arrangement of the strata on the left bank of the river Ogwen, from the Lingula beds downward.† (Fig. 70.)

No. 15 represents the dark bule slates above the Lingula grits; Nos. 14 and 13 the Lingula grits and slates; 12 to 6 the strata just described in the Penrhyn quarries, below which is the quartz porphry P. Between the faults *a* and *b* the usual succession of purple slate and grit occurs down to the conglomerate No. 1, which is probably not far beneath the surface at *b*. Between the faults *b* and *c* part of the same grits, and green and purple banded slates from 2 to 6, are repeated in an anticlinal curve, which widens on the south-west by Ffynnon-bach, as shown in the 1-inch map. Between the faults *c* and *d* the purple and banded slate No. 2 is again let in in an irregular space. The trigonometrical station above Pont-y-Coetmor stands on it. A narrow strip, about a mile in length, of the basement conglomerate (No. 1) is then let in between two faults, *d*, *e*, downthrows on the south-east and north-west. Pen-y-garth stands on it. The fault *e* again throws in the purple banded slate No. 2, from beneath which the conglomerates (No. 1) crop out in regular succession as far as the Aber and Dinlle fault *f*, where Lower Silurian beds are thrown in on the north-west near Llyn Cororion.

On Moel-y-Ci and in the neighbourhood of the valley of the Ogwen generally there is a considerable modification in the lithological character of the Cambrian rocks compared with those of Llanberis. Some of the slates become much more sandy, and occasionally absolutely pass into grits, so that the section differs in the details of its lower members from the type section at Llyn Padarn. Thus on the top of Moel-y-Ci there is a bed of conglomerate and grit unknown on Drysgol-fawr, but an equivalent of which may perhaps be concealed dipping towards the porphyry beneath the turbary. In spite of local variations, however, a glance at the map, with the assistance of the preceding diagrams, will show that as far north as the Ogwen the detailed structure of the country may be dissected. Beyond the Ogwen, on the east, the more simple arrangement of the rocks resembles that south-west of Llyn Padarn, above the porphyry, and, though much obscured by drift, I believe I succeeded in accurately laying down the general distribution of the rocks round Llanllechid. As this is also a country that has been worked for slate, I shall devote a few paragraphs to the explanation of its structure.

The uppermost Cambrian grits of Bronllwyd strike north across the Ogwen behind Tan-y-graig, dipping a little south of east at angles of about 60°. (*See* Map 78 S.E.) Being thrown down to the west by the fault that runs through Afon Fridd-las, they spread westward to Bethesda over a space more than half a mile in width, rising in an arch, the top of which being partly denuded a portion of the upper green and purple slates reach the surface in the form of half an oval, between the turnpike road and the north-west fault. (Fig. 71.) This fault passes down the course of the river from the bridge above Bethesda to Pont-y-Coetmor, and may be termed the Ogwen fault. Being a downthrow on the N.W. it throws the uppermost Cambrian grit against the lower slaty series that lies beneath the turbary, opposite Bryn-llys, as shown in the one-inch map. A little beyond, on the right bank of the river towards Coetmor, the lower part of the lower grits associated with the lower purple slates follow a curved and faulted line, as shown on the map by Llanllechid, and

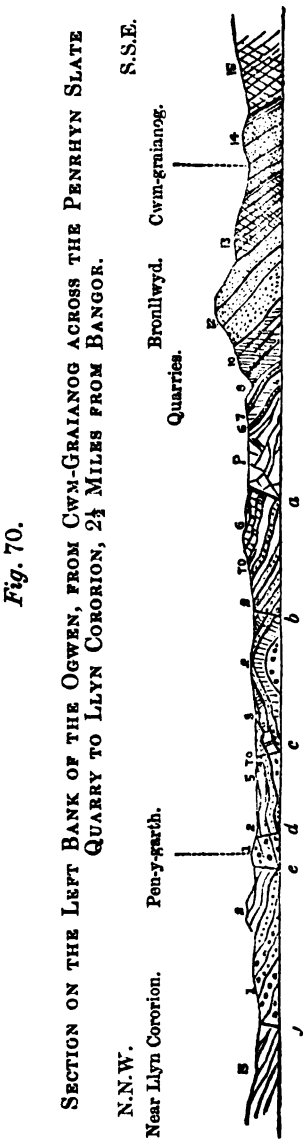
* 2½ miles S.S.E. from Bangor.

† It corresponds to the 6-inch sections, sheets Nos. 28 and 31, and plate 28, fig. 3, from Snowdon to Dinas, across the Llanberis country, and to diagram No. 65, p. 183, on the N.E. side of the lakes, and at a glance brings the positions of the same beds before the eye in the nearly parallel valleys of the Ogwen and Llanberis.

abut on the Aber and Dinlle fault near the house called Tan-y-marian, about 2 miles S.E. of Bangor. The above description will be made plainer by reference to the following line of section drawn close on the right bank of the Ogwen, from Felin Cochwillan* to Bwlch-hela,† in which the arrangement of the strata is as follows, fig. 71 :—

Fig. 70.

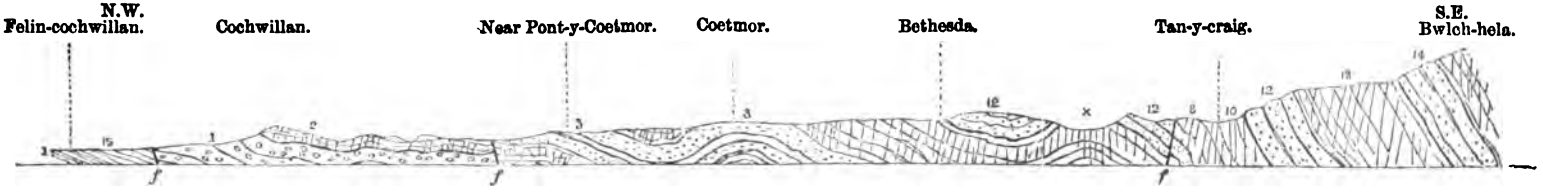
SECTION ON THE LEFT BANK OF THE OGWEN, FROM CWM-GRAIANOG ACROSS THE PENRHYN SLATE QUARRY TO LLYN CORORION, 2¼ MILES FROM BANGOR.



* Opposite the 27th milestone on the Holyhead road, on the right bank of the Ogwen.
† A mile and a half south-east of Bethesda.

Fig. 71.

SECTION ON THE RIGHT BANK OF THE OGWEN FROM FELIN COCHWILLAN (2 MILES S.S.E. FROM BANGOR) TO BWLCH-HELA ABOVE NANT FRANCON.



1. Conglomerate. } Cambrian.
2 to 12. Slates and Grits }
13. Lingula Slates } Silurian.
14. „ Grits }
15. Dark slates, Lower Silurian.
f. Faults.

N

From Bwlch-hela to Tan-y-graig the Lingula grits (14) and slates (13), and the Cambrian grits (12), and slates, probably as low as the "blue slate" (8), retain the same general position that they have at and above the Penrhyn quarries. The ground by Tan-y-graig is partly obscured by drift, but I have no doubt of the existence of true Cambrian slate in a narrow space about a fifth of a mile in width between Ogwen bank and the country a quarter of a mile N.N.E. of Ciltreflys, where it is cut off by the fault which here throws the dark Lingula slates against it on the east bank of Afon Fridd-lâs, a little above the Penacneddi road. The rocks are thus partly repeated, and in the line of section the grits (No. 12) roll over in an arch, again bringing the upper purple slates to the surface under × in the section. The 30th milestone must be about the middle of the curve. Cropping again to the west in the town of Bethesda, the whole of the rocks, including the green, upper purple, "blue," and part of the lower purple slates rise between the town and the boss of grit No. 3, on which stood the ruined mansion of Coetmor. Certain of the intermediate grits below the "blue slate" seem here to be entirely concealed by drift, or else (more probably) they have thinned away, or their equivalents have become slaty in texture, so that the grit on which Coetmor stands is in the midst of the lower purple slates, and probably represents the grit marked No. 3 on the shores of Llyn Padarn and on Drysgol-fawr. (Figs. 62 and 68.)

Coetmor, as marked on the 1-inch map, stands on the centre of an arch of grit, dipping east, north, and north-west, and the lower part of the slaty beds that rest on its eastern dip curve round a little north of Coetmor, and lie in a synclinal trough nearly a third of a mile in width between the grit on which the mansion stood and the road leading down to the bridge across the Ogwen called Pont-y-Coetmor. Here the same grit rises with a south-eastern dip, striking by Coed-isaf towards Llanllechid, and from thence by Rhiw-goch† to the Aber and Dinlle fault *f**, on the west of which Lower Silurian rocks (15) are thrown in. Underneath the grit the lower part of the purple slates (2) crop out west of Rhiw-goch. They rest on the basement conglomerate (1), and are generally very sandy, and sometimes almost gritty in quality, representing in part some of the lowest beds of grit that lie north-east of Moel-y-Ci. To explain the nature of these local variations, I may recall the fact that, whereas both the middle and upper grits and conglomerates thin out and disappear on the south between Llanberis and Bettws Garmon, the opposite result takes place in the extension of these strata from Llanberis northward, several new beds of grit appearing between the lakes of Llanberis and the Ogwen. Again, that certain grits that are separate on the west seem to coalesce on the east side of that river, either by a thinning of the intermediate slate or by its assuming a more sandy texture. This is especially characteristic of the rocks east and north of Moel-y-Ci, as for instance near Waun-hir, where sandy slates become rapidly mingled with thin bands of conglomerate, which as rapidly disappear, probably evincing the shallowness of the near-shore waters in which the original sediments were accumulated.

The country for some miles north and north-west of Bethesda is generally so deeply covered by drift and boulders that it is impossible to unravel its details with the same accuracy as in the section last described. Possibly certain beds of grit occur between the purple and blue slate quarries north or north-east of the Holyhead road, and these grits may crop up to the drift in the great triangular space coloured as Cambrian slate on which Llanllechid stands. However this may be, the following diagrams will explain all the larger relations of these rocks north of Bethesda.

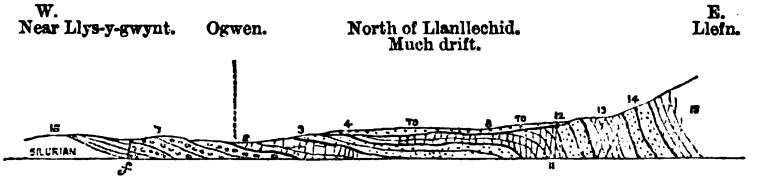
This section, Fig. 71, is drawn on an east and west line from the Lower Silurian slates of Llefn,‡ to the neighbourhood of Llys-y-gwynt, about 2 miles S.S.E. of Bangor. Below the Lingula grits and slates (14 and 13), the Cambrian grits (12) crop out, from underneath which, on the west, the ordinary green, "blue," and purple slates (4 to 11) rise towards the surface, obscured by drift; and as they occupy a broad space north of Llanllechid they probably roll to the west in the manner shown in the diagram. Beneath these are the lowest grits, purple slates, and conglomerates (3 to 1) in the bed of the Ogwen. Lower

* Three miles E.S.E. of Bangor.
† About half a mile N.W. of Llanllechid.
‡ About a mile east of Llanllechid.

Silurian strata (15) are as usual thrown in by the Aber fault (*f*) against the lowest Cambrian strata of the district.

Fig. 72.

SECTION ACROSS THE CAMBRIAN SLATES, &c., NEAR LLANLLECHID.

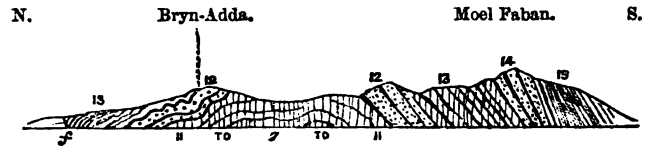


15. Blue Slates
14. Lingula Grits } Silurian.
13. „ Slates
12. Grit
4 to 12. Purple and "blue" Slates, &c.
3. Grit } Cambrian.
2. Purple Slates.
1. Conglomerate.
f. Aber and Dinlle fault.

A glance at the map will show that the uppermost Cambrian grit strikes from Bethesda for about 3 miles a little east of north, dipping easterly at an angle of about 45°. It then bends over to the north and west in an anticlinal curve, which, if entire, would form a kind of half dome, but the oval continuation of the grit being thrown down by a north-west fault which passes across Moel Wnion, the purple and green grits and slates abut on the Lingula flags of Fridd-y-Fedw. On the northern side of the anticlinal line, the Cambrian grit, much contorted, occupies a space of about half a mile in breadth, and striking westward about a mile, it abuts on the Lower Silurian beds on the line of the Aber and Dinlle fault, a little south of the third milestone on the Bangor and Aber road. The arrangement of the rocks is approximately represented in the following diagram, which runs north from Moel Faban across the turnpike road about 3½ miles east of Bangor.

Fig. 73.

SECTION FROM THE BANGOR AND ABER ROAD TO MOEL FABAN.



15. Blue slates.
14. and 13. Lingula grits and slates.
12. Cambrian grits.
11 to 7. Green, purple, and "blue" slates, which bending over in an anticlinal curve throw in the grits No. 12 on the north, together with a small part of the lowest beds of the Lingula flags 13′, in a triangular space bounded on the north-east by the fault at Tan'rallt. (*See* Geological Map 78 S.E. and Fig. 73, p. 202.)
f. Aber and Dinlle fault.

In Nant Francon, the part that corresponds to the Cambrian rocks of the Snowdon section (No. 3, pl. 28), attains a thickness of about 2,000 feet. The lower part of the strata below Moel-y-Ci being added gives altogether about 3,000 feet, of which from 700 to 1,000 feet consist of slaty rocks, some 300 feet of which are coarse and sandy. *In neither section do we reach the base of the Cambrian strata* which is cut off in one region by the quartz porphyry, and in another by the Aber and Dinlle fault, but as far

as the beds are known, coarse grits and conglomerates form by far the larger proportion of the series. These coarse beds increase in quantity as we proceed from Nant-y-llef* northwards to Nant Francon,† partly by passage of muddy into sandy and gravelly sediments, and on the whole these coarser sediments must be considered as typical of the Welsh Cambrian strata, both in Merionethshire and Caernarvonshire. In the 8,000 feet of these rocks in Merionethshire there is but little slate, and that principally in the lowest known part of the series, and even the 700 or 1,000 feet of interstratified slaty beds in Caernarvonshire are quite subordinate to the grits and conglomerates.

The capricious variations in the lower part of the Caernarvonshire Cambrian strata, coupled with the presence of so much coarse conglomerate in the lower beds, indicates the neighbourhood of an older rocky land during their deposition. The structure of this land may be partly inferred from the nature of the pebbles in the conglomerate, which are waterworn, and consist of purple and black slates, quartz-rock, felspathic traps, quartz porphyries, and jaspers. The vast thickness of the Cambrian rocks of Merionethshire and Caernarvonshire tells of an older territory that may have been hilly or even mountainous, from the waste of which the conglomerates and other sediments were formed; and furthermore, the country from which the pebbles in the conglomerate were derived must have lithologically resembled in some respects North Wales as it now stands, but except in these pebbles no trace of that land remains in or near North Wales.

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* Map. 75 N.E. † Map 78 S.E.

CHAPTER XXIV.

The Rocks between Bangor and Caernarvon, &c.

General Description.—Arenig Beds.—It has been repeatedly stated (p. 173, &c.) that a great fault runs from Aber to Dinlle on the coast of Caernarvon Bay, which throws Lower Silurian strata down on the north-west against the lower parts of the Cambrian beds of Llanberis and the Ogwen.

Between the mouth of the Ogwen and Aber the coast line first consists of very low cliffs of glacial boulder clay, and near Aber of remodelled gravels, with a line of recent shells at their base just above the level of the tide; but the nature of the rocks is well shown on the shore between the Ogwen and Port Penrhyn at Bangor. From Port Penrhyn towards the bath house there is an ascending section, the strata of which generally dip a few degrees south of east, first at angles of about 60°, then for a space becoming nearly vertical, and afterwards near the bath house at about 32°. They mostly consist of banded slaty rocks, very micaceous and much but badly cleaved, so that it is difficult to make a clean fracture in the planes of bedding, though the upper surfaces of some of the outcropping strata on the shore are sufficiently plain. Just before reaching the bath house the slaty beds contain curious kidney-shaped sandy concretions from six inches to one or two feet in length.

Rocks of the same general character are seen at intervals on the north-west side of the Aber and Dinlle fault all the way from Penrhyn Castle to Caernarvon and Dinlle, and these slaty strata, without any intervening fault, distinctly overlie the rocks coloured on the map as Cambrian, and the long and broad crystalline mass that runs between Caernarvon and the neighbourhood of Bangor. Thin bands of grit are occasionally mingled with the argillaceous strata, but it nowhere occurs in one long thick band like that at the top of the Lingula slates which runs from the Pass of Llanberis to the Aber river, and as will be shown, the slates between Penrhyn Castle and Caernarvon belong to a higher geological horizon, that of the Arenig slates, unless it may happen that in places near the Aber and Dinlle fault some part of the Llandeilo beds as yet undetected may possibly be discovered.

Though often much concealed by glacial detritus, these strata are well exposed close to and overlying the Cambrian rocks on the hill for about a mile south of Port Penrhyn, dipping E.S.E. about 45°, the Cambrian beds dipping in the same direction. The same is the case further south at Bryn-mawr, where the beds dip easterly at 58°, and they are again exposed as a micaceous slaty grit at Cefn-mawr about a mile north of Pentir, near which by the mill cleaved slaty strata are seen, the cleavage inclined W.N.W. at 80°. They are again seen between Llanddeiniolen and Dinas Dinorwig dipping south-east against the fault, also

south of Llanrug dipping north and striking towards the fault, and close by at Nant Ho'l-gwyn north-westerly at 15° to 20° or from the fault. An excellent section is also seen on the banks of the Seiont, between the mouth of the river and the bridge on the turnpike road, and occasionally beyond that point. Further south the Silurian slaty strata are seen at Pandy and Dinas Dinoethni, near Llanwnda, while south of Caernarvon at Cefn-Coed, east of Llanfaglan, they are seen dipping south-east by the southern margin of the greenstone.

Nowhere do these strata precisely resemble the Silurian slaty beds of Nant Francon and the Pass of Llanberis, perhaps partly owing to differences in original material, but also to the comparative absence of, or at all events the much less perfect quality of the cleavage, probably indicating a less degree of lateral pressure (deep beneath superincumbent strata) exerted on the rocks of this part of the country at the time that the first great contortions of the masses of rock took place that now form North Wales. This less perfect consolidation often gives to the Silurian beds between Bangor and Caernarvon more of a shaley than of a slaty texture. Near Caernarvon they consist of dark brown and black slaty micaceous shales with occasional sandy beds, sparingly fossiliferous. There, by the bridge, a greenstone dyke lies in the bedding hardening the strata at the points of contact. Similar black shales were proved beneath the boulder beds in 1848, in search for coal between Coed-mawr and Pentre-Seiont, close to the road between Caernarvon and Llanberis, by the misdirected industry of certain speculators led by a "practical man," himself misled by the black shaley character of the rocks and the wetness of a soil fertile in rushes, like many of the coal-measure shales.

Cambrian Strata.—Having described the lithological character and general arrangement of these slaty and shaley strata, I will now turn to the more ancient Cambrian rocks on which they lie, and to the long crystalline mass between Bangor and Caernarvon.

These Cambrian strata are best seen near Bangor, the rocks further south being much obscured by glacial deposits. About two miles south of Bangor on the road about the spot marked by the C of Caerhun on the map, there are purple slaty beds and green and grey grits, and for more than a mile further north on either side of the road, as far as Nant Gwytheryn, purple and green grits and grey slates abound, dipping east about 45°. About Cae-seri and Minffordd, near this road, purple and grey fine sandy grits stand out above the cultivated ground in bold rocky bosses, the purple colour predominating, and in this respect quite recalling the hue of the Cambrian strata of Nant Francon and Llanberis, excepting that they are not fissile or affected by slaty cleavage. From thence going northward to the footpath bordering the pleasure grounds that overlook the railway station and the town of Bangor, the strata chiefly consist of altered purple shales standing vertically, interstratified with some beds of a green colour. They are hard and somewhat porcelanic. Close

above the town the strata dip a little south of east at angles of 70° or 80°.

Other good sections may be seen along the shores of Menai Straits south-west of Garth Point, and in the turnpike road and quarries in the fields south-west of Bangor, and in part of the grounds of Perfeddgoed. In all these places the beds are hard and splintery, sometimes purple and sometimes of a chloritic green colour, and fracturing with small irregular joints often coated with chlorite. Sometimes the beds are schistose, sometimes granular and gritty, and sometimes conglomeratic, especially in the lower strata. The structure of these conglomerates was well shown in the heaps of rubbish thrown out about 30 years ago at the mouths of the shafts sunk during the excavation of the railway tunnel. Like the Cambrian conglomerates near the porphyry of Llyn Padarn they are metamorphosed, and consist of rounded pebbles of quartz, quartzite, felspar-porphyry, quartz-porphyry, purple grit, blue and black slate, and green and red jasper. In these respects they also agree with the conglomerate at the northern base of Moel-y-ci and of the Ogwen near Cochwillan, thus in all probability indicating general identity of geological age in rocks so near to each other. This alteration and semi-fusion of the conglomerates *as they pass into* the quartz porphyry of Llyn Padarn becomes so decisive in the Cambrian strata south of Caernarvon that in Glynllifon Park and its neighbourhood (Map 75 N.W.) it is difficult to separate quartz-porphyry from altered grit, the felspathic looking base of the stratified rock often giving rise to the impression that it has undergone a kind of absolute fusion like some of the rocks of Llyn Padarn. If the rock were well exposed probably every stage between porphyry and grit might be observed between the western side of the porphyry and the sea, and much of the altered strata between Bangor and Llanddeiniolen greatly resemble the Cambrian rocks of Glynllifon. This, in connexion with the north-western downthrow of the Aber and Dinlle fault, easily suggests that the strata coloured as Cambrian on the map at Bangor and south-west by Llanddeiniolen, are a mere repetition of a low part of the Cambrian strata of the lakes of Llanberis and of the valley of the Ogwen, but for the most part in a more highly altered condition.

So much doubt has been thrown out as to the Cambrian age of these strata, on purely theoretical grounds, that from a re-examination of the area in 1876 I have somewhat added to the details given in the previous edition of this book. In this re-examination I was accompanied by Mr. Etheridge who did not require any arguments from me to convince him that they are true Cambrian rocks equivalent to the purple series of Llanberis and Cwm Ogwen, and who saw no reason to doubt the correctness of the judgment formed by Mr. Selwyn and myself in 1848. His unsolicited estimate of the varying colours of the strata was about 50 per cent. coloured purple, 30 per cent. green, and 20 per cent. grey, the last being chiefly grits. In other Cambrian regions in North Wales it is the grits that are chiefly grey.

The map that accompanies this volume, and the corresponding map on the scale of one inch to a mile, show that the Cambrian rocks of Bangor wedge out and disappear at Dol-deilo, about a mile and a half south-west of Llanddeiniolen. Beyond this the Silurian (Arenig) strata adjoin the mass of crystalline rock that runs from Twt Hill at Caernarvon towards Bangor.

Quartz Porphyry, &c.—On Twt Hill the rock consists of a mixture of felspar and quartz forming a distinct binary compound, such as was once called granitella, and is now often called aplite or granulite. But for the absence of mica it would be a true granite. Near Brithdir, a mile and a half south of Menai Bridge, the continuation of the crystalline mass is a purple quartz porphyry, and nearer the bridge a quartz porphyry much resembling that of Llyn Padarn in the Pass of Llanberis. Between these points and Caernarvon, though much of it is a quartz porphyry, it is not always easy to give it a definite name, for though still composed of felspar and quartz it sometimes passes into a rudely foliated rock, rising here and there in bosses through the glacial debris that fills the hollows. And yet though it never perhaps deserves the name of gneiss, to me it sometimes conveys the impression of stratified rocks in a very advanced stage of metamorphism, which for the most part may have originally consisted of the Cambrian strata that lie between Bangor and Dol-deilo, and perhaps of some of the Silurian strata that border it from Dol-deilo to Caernarvon. This may possibly be explained on the hypothesis of the metamorphic alteration of the stratified rocks in part, as at Twt Hill, beyond the point of fusion, and while the whole lay deeply buried under overlying strata during part of the Lower Silurian epoch. When compared with the porphyry of Llyn Padarn, it often exhibits more free silica, and in lithological character, as a whole, it may be said sometimes to come between the quartz porphyry of Llyn Padarn and the imperfect granitic rocks of Anglesey.

Fault and Carboniferous Rocks between Bangor and Caernarvon.—On the north-west this mass of porphyry is bounded by a north-east fault running parallel to Menai Straits, from which another fault seems to branch to Bangor, itself again breaking near the town into two branches between which Silurian strata, somewhat altered in places, are enclosed.

This great fault, like the Aber and Dinlle fault, is a downthrow on the north-west, bringing *unaltered* carboniferous limestones, conglomerates, sandstones, and shales against the porphyritic mass and the Cambrian rocks near Bangor. The conglomerates contain pebbles of the altered rocks and other neighbouring masses. All the altered rocks of the district were therefore metamorphosed before the deposition of the Carboniferous strata, and, indeed, I have no doubt that the alteration was effected before the deposition of the Upper Silurian strata, possibly in direct connexion with that contractile power that produced the first contortion of the Lower Silurian strata, before the deposition of the Upper Silurian beds began.

Arenig Beds.—Having now described the lithological characters and other circumstances connected with the Caernarvonshire rocks that lie north-west of the Aber and Dinile fault, the question still remains as to what stage of the Silurian series the Penrhyn and Caernarvon slaty beds belong. Resting as they do on strata believed to be of Cambrian age, Mr. Selwyn and myself at first supposed them to be Lingula flags,* but there are reasons that prove this view to be erroneous.

It has already been shown that the Lingula slates and grits have been traced to the north-east as far as the Aber river in the form of an anticlinal curve broken by five faults (Fig. 73), and the Lingula grit, much thinner than on Elidyr fawr, is last seen at Maes-y-gaer on the north-east side of the river in the form of an arch on the cliff dipping under the overlying slates at angles of about 20°. If the mapping of the country be correct from thence to the Pass of Llanberis, it is certain that the slates which overlie the Aber and Elidyr-fawr grits cannot be Lingula beds, and if the succession of subformations were necessarily always the same over the whole of Wales, it is natural to suppose that they should be Tremadoc slates, but for reasons that will be given further on this may well be doubted.

The Aber and Dinlle fault had escaped detection till its existence was clearly established by Mr. Selwyn between the Ogwen and Dinlle, and afterwards corroborated and extended by myself when in mapping the details of the Cambrian and Lingula bed strata north and north-east of Llanllechid I detected the western curve of the Cambrian grits, and their disappearance at a point where following the strike, if not cut off, they ought to be found trending towards Llandegai near Bangor.

This repetition of Silurian beds being admitted, it becomes apparent that the present structure of the country is the result of the denudation of a faulted anticlinal curve in the manner shown near the river Rothell in fig. 3, pl. 28, and in diagram No. 65, p. 183. More perfect relics of this bend, as already shown in this chapter, are found in the arch of Cambrian and Silurian rocks between Bethesda and the Aber river,† one side of which (on the north-west) has been cut off by the Aber and Dinlle fault. The arrangement of the Lingula beds affected by this arch between Moel-Wnion and Maes-y-gaer, near Aber, is so very remarkable, as a piece of physical geology, that I shall here give a special description of it, by the help of the map (fig. 73). The same coarse grits with the overlying slates are repeated five times in compartments formed by five north-west faults that intersect the country between the Dinlle and Aber fault and that which runs between the Aber river and Bryn-Efail. In each compartment

* The Menevian beds were not then known.
† *See* Map 78 N.E.

the grits lie in the form of solid half cones, marked *a*, *b*, *c*, or of parts of cones, as in *d*, *e*, in the following diagram:—

Fig. 74.

h. Purple Slate } Cambrian.
g. Grit }
f. Lingula Slates }
a, *b*, *c*, *d*, *e*. Lingula Grits } Silurian.
s. Slaty beds overlying Lingula beds }

The shaded space *h* represents the blue and purple slates, and the dotted bands *g* the Cambrian grits of Bryn Addu and Bethesda that overlie them. The blank portions *f* represent the Lingula slate; the remaining dotted spaces *e* stand for the Lingula grits;

and *s* shows the place of the Silurian beds above that horizon. The cause of the peculiar arrangement at the surface of the Lingula grits *a*, *b*, *c*, *d*, *e*, and of the overlying slates, must be owing to the whole mass having sloped downwards in an underground pointed anticlinal form, somewhat like half a cone, the apex of which was directed to the north-east, and different sections of it had been shifted and heaved up and down as it were in stages to certain levels between Woel-Wnion and Maes-y-gaer by four faults, the form of the ground having since been modified and the grits exposed by denudation. The whole must be looked on simply as the shattered continuation of the great broken curve, the anticlinal axis of which passes Maes-y-gaer near Aber, and from thence through Llanllechid and Moel-y-Ci, towards the entrance of the Pass of Llanberis, and one chief result with which we are now concerned, is the throwing in and repetition of Silurian strata on the north-west side of the Aber and Dinlle fault.

If we attempt to restore the curve above alluded to, we get approximately the amount of the throw of the Aber and Dinlle fault in places where, like those crossed by the Snowdon and Glyder-fawr sections* the data are tolerably perfect. To approach accuracy in this estimate certain considerations must be attended to.

It is plain that the quartz porphyry of Llyn Padarn is of later date than the Cambrian rocks, for the reason that they pass into it by metamorphism. It will in another place be shown that this alteration was probably of Lower Silurian date, but in no sense were masses of porphyry, like that of Llanberis, the cause of the faults and contortions of the Cambrian and Silurian strata, for they themselves partake of the contortions and are affected by the faults. The curves, for instance, of the beds of conglomerate and slate on Clegyr above Llyn-Padarn, spread half across the porphyry; and other like cases, give obvious hints that the molten mass was not protruded vertically like a great dyke, but rather that part of the strata once spread closely across its present surface, perhaps somewhat as it now stands. If so, then by restoring the denuded strata in a broad anticlinal curve in the manner shown by the dotted lines west of Dinas (section 3, pl. 28), we shall find that the Silurian beds have probably been thrown down on the north-west from about 2,000 to 3,000 feet; and if we apply the same sort of measurement to the Glyder-fawr section (No. 2, pl. 28, horizontal sections, sheet 31) only 4 miles off, the throw increases to between 4,000 and 5,000 feet.

The north-western downthrow along the line of the Aber and Dinlle fault being admitted, it becomes evident when taken in connexion with the foregoing arguments, *that the strata closely adjoining its north-west side must belong to a part of the Silurian series higher than the Lingula grits of Elidyr-fawr and Aber*, and indeed must represent some part of the slaty beds that overlie the arch of grit at Maes-y-gaer. These, as I have already remarked,

* Six-inch Sections, sheets 28 and 31.

we might at first sight naturally suppose should be Tremadoc slates, but whatever their age may be it is certain that the slaty Silurian rocks of Penrhyn and the Ogwen must be the equivalents of those that overlie the Lingula grits of Maes-y-gaer near Aber. Looked at in this manner as a purely physical question, it has always satisfied me that the blackish slaty beds which lie on Cambrian rocks and stretch from the Penrhyn promontory at Bangor to Caernarvon, are what used to be called Lower Landeilo beds and are now termed Arenig slates.

The only other light that has been thrown on the question is of a palæontological kind. In the strata on the shore of Penrhyn Park a single specimen of *Bellerophon perturbatus* was found by our collector, Mr. Richard Gibbs, and named by the late Mr. Salter. It occurred near the Bath house, and though the strata along that shore have been repeatedly searched for fossils (as late as 1875 by Mr. Etheridge and myself), no further discovery has been made. This fossil is well known as a common species in the Llandeilo flags, and is stated by Mr. Etheridge as occurring in the Arenig beds or Lower Llandeilo of Murchison, west of the Stiper stones.

In the dark micaceous shales on the banks of the Seiont, near Caernarvon, there were found, by Mr. Selwyn and myself, a few indeterminable fragments of a crustacean, and some poor specimens of *Didymograptus Murchisoni*, also named by Mr. Salter. This fossil is characteristic of the Llandeilo beds, and, as suggested by Mr. Etheridge, no doubt belongs to the *D. Murchisoni* var. *geminus* which is found in the Arenig beds.

In the summer of 1875 a new discovery was made by Mr. J. E. Marr, who in the slaty beds by the bridge across the Seiont, near Caernarvon, found the following fossils, a phyllopod, *Caryoceras Marri*, three trilobites, *Aëgilina Hughsii*, *Trinucleus*, and *Barrandia*, three brachiopoda of the genera, *Lingula*, *Discina*, and *Obolella*, a cephalopod, *Orthoceras caerecsiense*, and of hydrozoa *Didymograptus bifidus*, *D. indentus*, and *D. Murchisoni*, and this settles the question of the undoubted Arenig age of these strata. Considering that, heretofore, I have singly so long obstinately adhered to this belief, in spite of much grave opposition, it is satisfactory to have the matter decided at last on the most unquestionable palæontological authority, connected as it is with the supposed heresy, which I stuck to so long, of the unconformable overlapping of these Arenig beds across the Tremadoc and Lingula beds, so that in the neighbourhood of the Menai Straits they lie directly on Cambrian strata.

There is but little to add respecting the rocks of this part of Caernarvonshire.

Another great north-east fault, already alluded to (p. 200), cuts off the whole Silurian and Cambrian series from the neighbourhood of Garth point, Bangor, to Caernarvon, throwing down on the north-west rocks of the Carboniferous series (section 3, pl. 28).* These lower Carboniferous rocks, coloured blue in the

* Maps 78 S.W. and S.E., and Horizontal Sections, sheet 28, line 1.

map, are partly of the ordinary limestone type, but a great proportion of them are composed of shales, yellow sandstones, and quartz conglomerates more or less calcareous. They were probably formed in a sea, comparatively shallow, not far from shore. Under the limestones at Menai bridge, beds of deep red marl occur associated with quartz conglomerates, and the other beds with which they are associated seem to indicate that they belong to the Carboniferous series. Indeed throughout the Carboniferous rocks of Caernarvonshire and Anglesey red beds are not uncommon, for on the shores of the Menai between Caernarvon and Llanfair-is-gaer, and on the opposite shore between Menai-fron and the ferry house, there are red marls so bright in colour that they were originally mistaken for New red marl by persons not minutely acquainted with the structure of the neighbourhood.*

Underneath them at Llanfair-is-gaer there is a mass of conglomerate of a shingly and beach-like character, more particularly described at page 260.

Smaller Igneous Masses.—Four greenstone dykes (diorites?) cut in a north-western direction across the strike of the Cambrian strata near Bangor, one of them being amygdaloidal, with nests of orthoclase felspar sometimes half an inch in length. There can be little doubt that these dykes are of the some age as the greenstone dykes of the Penrhyn slate quarries, Llyn Peris, Llyn Padarn, the Menai Straits, near Bangor and Llanfair-is-gaer, and in Anglesey in general. In that island dykes having the same trend cut through all the rocks, inclusive of the Coal-measures, but not through the unconformably overlying Permian strata, and therefore it is presumed that all of them are probably of pre-Permian age.

Three masses of greenstone are intruded into the shales south and south-west of Caernarvon. The principal one, more than a mile in length, lies between Llanfaglan and the tram-road. It is one of the most marked greenstones in Wales, and consists of finely developed crystals of orthoclase felspar and hornblende with a little iron pyrites. Some of the crystals of hornblende are more than an inch in length.

* For further remarks on this subject see p. 260.

CHAPTER XXV.

The Rocks of Lleyn, or the Promontory between Caernarvon Bay and Cardigan Bay.

General Description.—Although the rocks of Anglesey are stratigraphically, and to a great extent lithologically, continuations of those on the Caernarvonshire side of the straits, it will be convenient first to describe the long promontory of Lleyn, because of its more direct union with the country described in last chapter.

Like Anglesey it partly consists of metamorphic rocks, which are supposed to be of Cambrian age, and of Lower Silurian strata, through which numerous bosses of rock protrude of a syenitic and dioritic character, being various compounds of felspars, hornblende, and occasionally free silica. Some of these are of great extent, and in Bwlch-mawr and Moel Penllech, Yr Eifl or the Rivals, Carn Boduan, Mynydd Nevin, Carn Madryn, Mynydd Mynytho, Mynydd-y-Rhiw, and other minor heights, they generally rise high above the plain of glacial drift that shrouds so much of the country, and thus form the loftiest hills of the district. The stratified rocks, indeed, generally lie in ground so low, and, except on the coast cliffs, they are mostly so obscured by sands and marine boulder clays that it is difficult to make out the details of their stratification. In the main, however, they are arranged in a rude synclinal curve which, broken by faults and invaded by the sea of the bays of Caernarvon and Cardigan, is a continuation of the great Silurian basin of which Snowdon forms the centre between the Cambrian grits of Merionethshire and those of Nant-ffrancon, Llanberis, and Llanllyfni (map 75, S.W.). This fragment, though broken, by minor faults, dips northward as a whole beneath the pisolitic iron ores in the slaty Arenig strata of Llanengan. Viewed in this light the grits and slaty shales that form the promontory between Penrhyn-du and Mynydd Cilan, together with St. Tudwal's Islands, belong generally to the Lingula flag series, as proved by fossils found by Mr. David Homfray, Mr. Etheridge, and myself in 1876, a little north of the high sea cliff of Pared Mawr, Porth Ceiriad.* No overlying Tremadoc slates have been proved in the area. Possibly they may be cut out by the east and west fault that runs between Porth-bach and Castell, but as that fault, like others in this area, seems to be of small amount, it may be that the Tremadoc slates, like part of the Lingula beds, have changed their lithological character, or possibly that they have thinned away or been overlapped, and do not anywhere crop to the surface in this particular district.

* These strata unlike the ordinary Lingula beds, to a great extent consist of massive beds of grit, and were, with much hesitation, considered by Mr. Selwyn and myself as belonging to the Cambrian grey gritty series of Harlech. The fortunate discovery of Upper Lingula flag fossils has solved the difficulty.

The north-west side of the synclinal curve of the Silurian rocks of Lleyn, consists of a long band of chlorite and mica schists, which form the coast between Bardsey Island and Porth Dinlleyn, and in general terms are believed to be the equivalents of the Cambrian rocks of Llanllyfni and the coast north of Clynnog Fawr, and of the equivalent strata of Anglesey, which they very much resemble.

The Silurian rocks of the whole area west of Traeth-Mawr, from position and the evidence of fossils, consist, as far as known, of Lingula flags, Tremadoc slates, Arenig and Llandeilo slates, and Caradoc or Bala beds. The unbroken continuity of the boundary lines sufficiently indicates their position, but even if the drift were removed, it is very improbable that they should be found adjoining the Cambrian rocks between Nevin and the neighbourhood of Penllech. However south of that region at Llanfaelrhys, east of Aberdaron, a meagre list of fossils points to the presence there of Arenig slates, mentioned in the previous edition as "a low part of the Llandeilo flags," by which in those days was meant the Lower Llandeilo beds of Murchison, and possibly the slaty beds of Aberdaron may belong to the same series. The fossils alluded to are *Ogygia Selwynii*, and another tail of the same genus, a *Lingula* like *attenuata*, another broader species, *Didymograptus geminus* a variety of *Murchisoni*, and numerous specimens of *Monoprion* (*Graptolithus*) *sagittarius*. There is good reason to believe that the same strata on the south side of the synclinal curve are faulted against the Lingula beds of St. Tudwal's, and this is strengthened by the occurrence of pisolitic iron ore like that of Tremadoc in the strata at Llanengan and Abersoch, a short distance north of the grits of Penrhyn-du and Porth Nigel. Caradoc or Bala beds form, however, the main mass of the country west of Criccieth, fossils of many of the usual species having been found near Pwllheli, Boduan, Llanystumdwy, and other places.

The igneous rocks of the area, unlike those of Snowdon, are as a whole not interbedded with the strata, though a good example of bedded ashes occurs at and north of Pwllheli. The rest of the igneous rocks may be briefly described as bosses surrounded by altered strata. Some are felspar porphyries, some greenstones with much more felspar than hornblende, and others of greenstone (diorite) in some of which hornblende and in others felspar predominates. Occasionally the different varieties pass into each other.

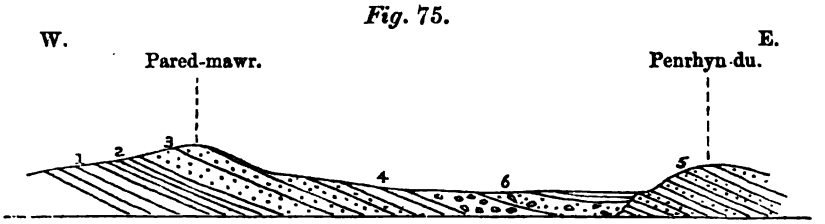
Lingula Beds of Penrhyn-du, &c.—The following details may be found locally interesting.

South of the fault that bounds the blue Arenig slaty beds of Llanengan and Porth-bach, the strata consist of hard gritty quartzose sandstones dipping a little north of east at angles of from 25° to 45°, and their strike is nearly coincident with the trend of the cliffs. St. Tudwal's Islands are formed of thick and thin beds of hard light grey siliceous grits interstratified with dark blue gritty

shales. The same kind of strata with an average east and north-easterly dip, continue south as far as Trwyn-yr-wylfa, where the rocks consist of fine banded grits or sandstones dipping nearly east, at an angle of about 25°. West of this point in Porth Ceiriad there is a low cliff of fine muddy silt well stratified, overlying beds of rounded gravel and boulders with ice-scratched stones, and this is underlaid by an angular breccia of post-tertiary date, resting on the slaty strata. From Trwyn-llech-y-doll to Trwyn-y-cilan, and from thence to Mynydd Cilan and Castell, near Llanengan, the rocks of the coast consist of grey grits, both coarse and fine, with beds of interstratified slaty shales.

The general section in Porth Ceiriad is as follows, from west to east in ascending order.

Fig. 75.



1. Light coloured slaty beds.
2. Dark slaty beds.
3. Quartzose grits.
4. Dark blue slaty beds and thin grits.
5. Banded grits.
6. Shingle, boulder beds, gravel, and fine muddy silt.

The cliff of Pared Mawr is about 340 feet in height, and large landslips lie on part of its seaward side at the west end of Porth Ceiriad. The lowest strata, No. 1, consist of light greyish blue slaty beds well banded, and very like some of the ordinary Lingula flags. They contain large nodular concretions of quartzose grit. Above these are blackish or dark bluish-grey slaty beds, No. 2, also containing large gritty concretions, and these are overlaid by quartzose grits, No. 3, sometimes in thick bands, both fine and coarse in structure, on which lie slaty beds interstratified with thin grits, No. 4.

Some of the strata are largely ripple marked like the Lingula grits of Cwm-graianog in Nant-Francon, and altogether in this bay these beds on a smaller scale so much resemble the Lingula beds of Llanberis and Nant-Francon, that I almost expected to find in them the well-known Annelid *Cruziana semiplicata* originally found by me in the Lingula grits of Cwm-graianog.

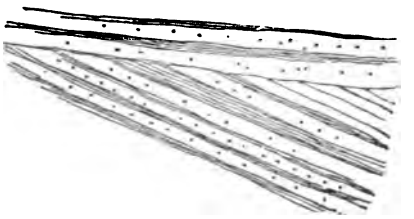
At this point the section of the rocky strata is broken off, and in the cliff the slaty beds, No. 4, are overlaid by various superficial deposits, and that which directly lies on No. 4 consists of shingle made of the waste of the underlying slates. This shingle dips to the east, probably in the original angle of deposition. It is mostly quite sharp and angular, and suggests the idea that it may be a sub-aerial accumulation formed during part of the glacial epoch. Boulder beds, gravel, and fine muddy stratified silt overlie it towards Trwyn-yr-wylfa, where the beds, No. 5, appear in a bold

promontory formed of fine branded grits and sandstones dipping east at 25°.

On the eastern side of Trwyn-yr-wylfa, near Pistyll-cim, the beds are interstratified with green bands and red patches of a species of jasper-like rock, sometimes lying in minor layers, which are twisted and contorted somewhat like the metamorphic Cambrian strata of the South Stack off Holyhead Island.

Between Castell on Pared-Mawr and Trwyn-Cilan, the cliffs are formed first of light brown hard siliceous grits with a little fine conglomerate dipping easterly at angles varying from 22° to 30°, and beneath these, on and near Trwyn-cilan, the beds consist of grey slaty shales and grits, with coarser grits on the western side of the point. On the coast north of this, as far as the sands of Porth Nigel, the rocks dip easterly, generally at angles varying from 30° to 36°, being for the most part grey and brown micaceous grits and slaty shales. The grits are occasionally somewhat felspathic, and the shales are sometimes almost black. In a little bay at the base of Trwyn-llech-y-doll near the south end of the great promontory there is for a few yards an appearance of unconformity in some of the strata, but probably it is merely a case of false bedding.

Fig. 76.



There are no genuine purple strata in the whole promontory similar to that of the undoubted Cambrian slaty strata of Merionethshire, Nant-ffrancon, Llanberis, and Bangor, but from the effects of weathering some of the slaty beds assume a purplish hue on the surface and in the joints, which, in the absence of fossils, and the great development of thick bedded grits originally helped to induce the now exploded idea that the whole might belong to the Cambrian series, especially as in that series in Merionethshire blueish slaty beds occasionally occur.

Fossils.—It was in a small opening by an unnamed cottage, on the south side of the road a little north of Pared-Mawr, that I had the good fortune to find the head of *Agnostus princeps* (formerly *pisiformis*), which a few days after led to the discovery by Mr. Homfray and Mr. Etheridge of *Lingulella lepis* and *Olenus scarabæoides* in pale grey slate with rusty planes. This slate is probably the inland continuation of the beds marked No. 1 in fig. 75, and the fossils as far as they go, show that these strata belong to part of the Upper Lingula flags. It may be argued from this that the rocks of Trwyn-yr-wylfa and Penrhyn-du, which dip east at 25°, may therefore belong to the Tremadoc slates, and in the absence of discovered fossils, I see no reason to

object to this, although from the west to the east side of the whole promontory from Mynydd Cilan to Penrhyn-du, the total thickness of the strata cannot be more than from 1,200 to 1,300 feet thick, and may probably be 100 feet or more less.

In the nearest area where Tremadoc slates occur, a little east of Criccieth, they are only about 200 feet thick, and in that immediate region the base of the Lingula flags does not rise to the surface.

Between Tremadoc and Ffestiniog the Tremadoc slates attain a thickness of about 3,000 feet, while the underlying Lingula flags have very nearly 4,000 feet in thickness.

Under these circumstances, if both Lingula flags and Tremadoc slates are present in the St. Tudwal's promontory, one or both must have rapidly thinned away towards the west, or, what is not unlikely, the diminished Tremadoc slate of the Portmadoc area may have entirely disappeared by an overlap of the Arenig strata as they pass under sea from the neighbourhood of Criccieth towards the country still further west that forms the promontory of Penrhyn-du and Trwyn-y-cilan.

This I incline to think was actually the case with regard to the deposition of the strata between the Menevian beds to the base of the Arenig slates in their range from the neighbourhood of Maentwrog westward into Lleyn, and the north-western part of Caernarvonshire.

It has been already stated that for many years the strata of this large promontory were considered to be of Cambrian age, as shown in the first edition of this book.

When first visited by Sir Henry de la Beche, he considered them more like the Denbighshire grits than any other strata with which he was acquainted. I several times visited the district, and at one time felt inclined to consider them the possible equivalents of the Lower Llandovery gritty series that occupies great part of the coast of South Wales between Aberystwyth and Dinas Head near Fishguard, for the following reasons:—

Near Aberaeron and Aberystwyth, in Cardiganshire, the rocks consist of beds of thick and thin hard grey sandstones interstratified with dark coloured slates, and the neighbouring dark Llandeilo slates of North Pembrokeshire are pierced by igneous bosses like the rocks of Lleyn. The kind of scenery is the same in both the districts that respectively form the north and south horns of Cardigan Bay, and this resemblance is owing to the hardness of some and the softness of other rocks in both areas, which have thus unequally resisted denudation. Much of the Cambrian rocks of North Pembrokeshire are also purple, like those of Merionethshire and Llanberis, and all these resemblances led me to compare the St. Tudwal's grits with the grits that form great part of the coast of Cardigan Bay from Aberystwyth to Dinas Head, near Fishguard. The discovery of Lingula flag fossils in 1876 near Pared Mawr has, however, definitely settled the matter, and all these difficulties have disappeared.

Faults.—An east and west fault runs from Pistyll-cim to the neighbourhood of Trwyn-y-fossle, on either side of which the dips show divergence of strike. As far as can be made out, however, the amount of the throw of the strata does not seem to be great. Several small dislocations are also seen on the coast cliffs further south. North of this on the coast several other small fractures are visible, some of which are lead lodes and others contain veins and spots of carbonate of baryta. A long east and west dislocation seems to run between the neighbourhood of Porth-bach to Castell near Llanengan, in which and in the cross courses, lead, blende, and copper pyrites have for long been extracted, sometimes with success. Some of the fractures run into the Arenig beds, but no fossils have yet been observed in the drab and grey slaty strata in the rubbish extracted from the mine. At Castell a level has been run into the east and west fault and lode, and in 1876 was about to be worked.

Cambrian Rocks between Bardsey Island and Nevin.

Before describing the Arenig, Llandeilo, and Bala beds of Lleyn, it will be convenient to notice the metamorphic rocks that occupy the north-western portion of the district of Lleyn.

On the north-west side of the synclinal curve, the metamorphic Cambrian rocks form a band (exclusive of Bardsey Island) 14 miles long from Bardsey sound to Nevin, and north-east of Penllech generally from a mile and a half to two miles wide, from whence a broader tract stretches southward to the east coast of Aberdaron Bay and Braich-y-pwll. On the coast cliff of this promontory, on the west side of the fault at Parwyd, there are beds of "green chloritic siliceous schists," against which abut beds of "dark blue "and grey banded micaceous sandstones and blue shales. At the junction "with the green schists they are much contorted, and apparently dip against "them"* in a manner that indicates a fault.

Fig. 77.

a. Chloritic Schist.
b. Silurian Shales, &c.
c. Drift.

On the coast in the inner curve of the bay the junction is obscured by drift, but above Bodwrdda, about a mile N.E. of Aberdaron, the Silurian beds strike towards the schists, dipping south-west about 40°, and this, with the occurrence of springs along the boundary line, denotes that a northern fault between the shore and Mynydd-Ystum also forms the western edge of this spur of schistose strata.

Beds of angular breccia, waterworn rounded gravel, and fine evenly bedded silt abut on the faulted strata and form the low cliffy coast as far as the west side of Aberdaron Bay. Ice-scratched stones occur amid these gravels, together with pieces of granite, porphyries, chalk flints, &c., &c., while on the shore, and evidently derived from the waste of the boulder beds, there are splended blocks of jasper of the kinds found in the metamorphic rocks of Lleyn, and of porphyritic granite which in the size and shape of its felspar crystals more nearly resembles that of Shap Fell than any other granite that I remember.

On the west side of the bay there are beds of Silurian slates, grits, and conglomerates, and a mass of well crystallised greenstone forming the splendid

* Selwyn.

headland of Pen-y-cil. These Silurian strata pass out to sea in the deep cliffy recess of Parwyd, opposite the rocky islet of Careg-du, and the boundary line, as already stated, seems to be a fault throwing the Silurian strata against the foliated contortions of the metamorphic rocks on the west.

It is probable that the long straight boundary line south-west from Nevin to Llangwnadl on the north side of the promontory may also be a fault, and, indeed, the same may be the case at the junction of all the Silurian rocks with the chloritic and other metamorphic schists as far as the fault seen on the coast between Trwyn-talfarach and Parwyd near Aberdaron. The drift is so great that the evidence is imperfect, though sufficient to show that the line, as drawn by Mr. Selwyn, is, as nearly as may be, correct.

Bardsey.—Bardsey Island lies nearly two miles from the mainland. A hill about 500 feet in height, precipitous towards the coast, forms its north-eastern part, and except on the shore the rest of the island consists of low land buried under glacial drift which forms the soil of several farms. The whole island is about a mile and three quarters in length. The rocks are of the same kind as those on the mainland opposite, and chiefly consist of highly metamorphic strata of a rudely gneissic character, with nests and lenticular masses of quartz and quartzite and occasional calcareous bands, together with a little jasper. Like the mainland the country has been moulded by ice during the glacial period, but the mammilated *roches moutonnées* have since been roughened by the weather.

Mr. Selwyn has briefly summarised the geology of Bardsey as follows:—

The east coast consists of "green, grey, and purple siliceous schists and "slaty rocks, patches of quartz rock, and a few thin grey calcareous bands, "all much contorted on a small scale, without affecting the general north-"westerly dip."* A lenticular piece of marble occurs on the coast about half way between Ogof-Morlâs and Pen Cristin. At Bay-y-nant the dip is north-easterly.

The Mainland.—From Bardsey Island to Nevin Mr. Selwyn describes the rocks as "chlorite and mica schists. A series of green, grey, and purple "schists, often very hard and siliceous, sometimes arenaceous and gritty, with "large and small veins, beds, and masses of quartz rock, also bands and "patches of calcareous rock and grey and pink siliceous crystalline limestone, "occasionally burnt for lime." These are pierced "by numerous greenstone "dykes, and contain patches of serpentine and veins and nodules of red jasper. "These beds are much contorted on a small scale, but their general dip is "north-westerly from 25° to 50°."† The small contortions alluded to are those little foliated twistings of quartz, micaceous, chloritic, and less altered sediment, so characteristic of many gneissose metamorphic rocks. Quartz veins on a large scale not in lines of foliation also often intersect the rock in all directions, and nests and lenticular masses of quartz and quartzite are common on the sea cliff of Mynydd-Mawr and the coast opposite Bardsey. Minute descriptions of many special places would scarcely convey more information.

On the mainland in and about Porth-felen there are "beds of greenish "grey, brown, and purple schists, mostly more or less calcareous, associated "with short veins and patches of red and white marble, intermingled with "veins and lumps of red jasper." These also are very siliceous and highly metamorphic. Between this and Braich-y-pwll, at the south-west angle of the promontory of Lleyn, the schists are exceeding felspathic, and in some places almost like hornstone. They are full of veins and strings of quartz. By Porth-llanllawen and for some distance inland purple beds are common, suggesting by their colour the recognised Cambrian purple slates of Llanberis and the purple strata of the altered rocks at Bangor.

Proceeding along the coast purple and white calcareous rocks, with veins and masses of red jasper, occur a little south of Dinas-oedd; and again, purple and pink limestone, full of veins of white carbonate of lime and patches of red jasper, in Borth-oer and at Morfa-trwyn-glas. They are associated with

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* All the quotations are from MS. notes by Mr. Selwyn except where the contrary is mentioned. The district was entirely mapped by him.

† Selwyn MS., on original copy of map 76 S.

green and purple schist and slaty and quartzose beds. Intermingled with these at Trwyn-glas are short lenticular beds and nodules of quartz rock, and the same kind of phenomena may be seen along the coast by Porth-y-gwylan and Rhos-hirdref. At Porthwen, on the west side of the promontory of Porth-dinlleyn, they have been described by Sir Henry De la Beche* as "hard siliceous beds, mingled with slate, occasionally micaceous." The general strike is about N.N.E. They are irregularly waved and crumpled, but the beds, as a whole, seem to be nearly vertical, but when strata have been foliated by metamorphism and are twisted about in many minor contortions the apparent dip is not always a safe guide. Between Edeyrn and the sea they dip north-west. A great number of trap-dykes, principally of hornblendic greenstone, pierce the strata between Porth-dinlleyn and Porth Penllech to the south-west. They are also numerous about Porth-ferin, and occur at many other points of this coast and around Bardsey Island.

"The rock at Porth-dinlleyn† is a kind of coarse green and purple serpentine, with nests of red jasper." Veins of the serpentine are observed to "dash in amid the slaty series at Porth-wen." Fourteen or 15 other patches of serpentine or serpentinous rock appear amid the schists to the south-west. Several of these are exceedingly small, and there is reason to believe that they are interstratified or largely interlaminated with the schists in such a manner that they must be considered as the result of metamorphism of siliceous and magnesian materials that formed portions of the stratified deposits. A good example of interlamination occurs at Careg, about two miles N.N.W. of Aberdaron, where streaks of lime, serpentine, and schist alternate with each other, more especially on the slope towards the sea. Neither is there anything in this opposed to Sir Henry Be la Beche's expression that veins of this rock are observed to "*dash in* amid the slaty series," for such metamorphisms occurring at great depths, it is easy to understand how certain portions of the strata that attained an absolute fusion under the united influences of moist heat and new chemical combinations might be injected into any fissures that might be formed in the adjacent less altered strata.

Silurian Rocks.—The Silurian rocks of Lleyn, though associated with numerous masses of igneous rocks, are never metamorphosed like the Cambrian rocks of this district, but resemble the ordinary Lower Silurian strata of much of the rest of the mainland of North Wales. Buried, however, in general, under deep superficial beds of stratified sand, gravel, and boulder clay, it is often difficult minutely to connect the country with the minor subdivisions into which the rocks of other parts of Caernarvonshire and Merionethshire resolve themselves. Even the igneous rocks elsewhere, assist in determining horizons by their interbedded character, but in Lleyn they are almost all intrusive, and afford no clue to the dissection of the country like the widely extended ashes of the two stratigraphical horizons of Cader Idris and Moelwyn, and of Snowdon. Nevertheless, if it be true, as Mr. Selwyn and myself believe, that the igneous mass of Llwyd Mawr represents the felspathic porphyry of Moel Hebog (diagram No. 59, p. 170), then the blue and black slates that rise from under it on the north-west must in great part represent the Caradoc or Bala and Llandeilo and Arenig beds immediately west of Snowdon and Moel Hebog (map 75, N.E.), and their position in relation to the Cambrian strata north of Clynnog-fawr proves it.

Other circumstances bear strongly on this subject. At Bettws Garmon, on the road from Caernarvon to Beddgelert, beds of

* MS. note. † Sir Henry de la Beche's MS. notes.

Pisolitic iron ore dip south-easterly at angles of about 52°, and are well shown in a line of abandoned quarries that strike N.N.E. up the steep slope of the hill between the Cambrian grit and slate and Moel Eilio. The Cambrian slates and grits below them dip in the same direction at 40°. On the high cliffy ground of the south-western flank of Moel Eilio, slaty rocks of Llandeilo or perhaps Caradoc age dip south-easterly and are seen to overlie them. The total thickness of the strata between the Cambrian rocks and the iron ore beds at the top of the Arenig strata, cannot be more than from 1,000 to 1,100 feet, as measured by protraction. No fossils have yet been found in these rocks.

The general strike of the strata at Bettws Garmon, would lead them south-west through Llyniau-Nant-y-llef towards Mynydd Llanllyfni, but no signs of the ferruginous beds have yet been observed, till we get to Trwyn-y-tâl on the coast about a mile north of the seaward slopes of Yr Eifel or The Rivals. There beds of pisolitic iron ore are found, precisely resembling those of Portmadoc and Bettws Garmon, and in the opinion of Mr. David Homfray, Mr. Etheridge, and myself, there is no reason to doubt that they all lie on the same stratigraphical horizon, viz., that of the Arenig beds. At Trwyn-y-tâl they were worked about 14 years ago, and are said to lie in two bands, a red one and a black one, and though the dip of the strata is obscure owing to the slaty cleavage of the rocks in which they lie, there is no doubt that they run in the general strike of the stratification.

The only other place in Lleyn where similar rocks occur, is at Llanengan a little north of the Lingula beds of the large promontory between Porth Nigel or Hell's Mouth and St. Tudwal's Road. There, near the grits and for some miles further north, dark blueish grey slaty strata generally dip nearly north at angles varying from 22° to 50°, and in them, not far north of the fault and lead lode, beds of pisolitic iron ore occur, identical in general structure with those in the Arenig beds elsewhere. There is no written record preserved of fossils from this locality, but I have a recollection of graptolites having been found at Llanengan, and if so there can be little doubt that they were of species belonging to the Arenig slates.

Assuming that these strata at Llanengan are true Arenig beds, there is no room for the Tremadoc slates between the pisolitic iron ores and the grits that lie south of the east and west fault that runs between Castell and the neighbourhood of Porth Bach, and unless the gritty series immediately south of that fault represent part of the Tremadoc slates, then it may be said that the whole of these strata may be cut out by the fault which is believed to have a downthrow to the north. Considering the thinness of the Tremadoc slates on the north coast of Cardigan Bay near Criccieth (only 200 feet) this would not be a remarkable result, but where seen on the coast, all the faults of this neighbourhood seem to be so small, that they look more like minor fractures than faults of importance, and I incline to think that the displacement of the strata *by throw* must here be so insignificant that it has

little or no effect on the regular succession of the strata. In that case it possibly may be, that the Tremadoc slates are altogether absent in this more western part of Caernarvonshire, and that the actual succession of strata going northward consists of Lingula beds, Arenig slates, and Bala beds, the last of which are well seen at Abersoch, where undulating strata of dark blue slaty shales with grey gritty bands occur, which contain the same general assemblage of fossils as the Bala beds of Pwllheli.

West of the promontory between St. Tudwal's Road and Porth Nigel, the low coast cliffs consist of stratified sands, gravels, and fine silt, with boulder clay, 40 feet of which are sometimes exposed, and this material covers the country in mass from Llanengan to Llangian, from thence north-west to Bottwnog and Bodceri, and thence southward to the shore east of Rhiw, on the eastern side of the large igneous boss of Mynydd-y-Rhiw. Going north no dips are seen in this part of the country till we reach the neighbourhood of Nanhoron-isaf and Bottwnog, and though it is probable that the Arenig beds may extend beneath part of the drift to the neighbourhood of Rhiw, there is no doubt that the first visible slaty strata between Llangian and Bottwnog on the northern edge of the drift belong to the Bala beds.

Further west between Porth Nigel and Aberdaron the rocks on the coast become in part more clear. North of Trwyntalfarach in the Bay of Llanfaelrhys, there are beds of dark slaty shales which dip south-easterly, and seem to abut on the intrusive greenstone of Penarfynydd, and these at intervals occur in patches along the cliff as far westward as Maengwenonwy, opposite which, a small tract of fine grained grey and banded grits or sandstones and dark arenaceous shales rest on the greenstone, dipping S.E. at an angle of about 30° as described by Mr. Selwyn in his MS. map. The strata of this region are fossiliferous and have yielded *Didymograptus Murchisoni*, *Ogygia Selwynii*, and *Lingula attenuata*, so that there can be no doubt that they belong to the Arenig beds.

Further to the south-west, forming the promontory called Trwyn-y-Penrhyn, there are dark grey and black arenaceous micaceous shales, with thin beds of grit and banded sandstone similar to the neighbouring strata on the east. They dip south-easterly against the greenstone of Porth-lleiddiad, and are faulted against the metamorphic Cambrian rocks at the east end of Aberdaron Bay. Westward to Aberdaron glacial detritus entirely buries the rocky strata (*see* p. 211), but it seems not improbable that northward towards Mynydd Ystym the same Arenig beds may extend, being faulted against the metamorphic Cambrian strata. These slaty rocks may be seen at Pandy dipping S.E. at 40°, and in the bed of brook about half a mile north of Aberdaron dipping N.N.E. at 35°. No fossils having been found at these places the precise horizon of the strata remains somewhat uncertain.

On the west side of Aberdaron Bay as far as Porth-meudwy, and from thence west of the greenstone to Parwyd, there are beds of quartz conglomerate and micaceous grey gritty sandstone overlaid by slaty beds which form the heart of the precipitous Cove. At this spot, in the Cove, it is stated that Sir Henry de la Beche found "*Favosites* (*Stenopora*) *fibrosa* and *encrinite stems*." I am unable to verify this statement from any written document, and these particular fossils from this place are not certainly known to be in the survey collections. I have, however, a distinct recollection of the statement being made by Sir Henry of the discovery of fossils at Parwyd, and it was considered at the time to be of value considering the general obscurity at that time of the geology of Lleyn. The "*Favosites fibrosa*" was said to be "the narrow branched variety," whatever that may mean, for there are many varieties of this coral, but this genus has not heretofore been found lower than the Llandeila flags. To what genus the *encrinite stems* belonged it is now impossible to say. The oldest known British crinoid is *Dendocrinus Cambrensis* from the Lower Tremadoc beds of Ramsey Island, and there is therefore no reason why encrinites may not be found in the Arenig slates. Altogether, such as it is, the evidence would rather tend to show that the strata belong to the Llandeilo or Bala beds, faulted against the very siliceous foliated and contorted schists and quartz rocks of the west side of Parwyd Cove (fig. 77).

It is remarkable that the strata of Lleyn above the Arenig beds are much more fossiliferous than the Bala beds below the igneous series, that strike from Nant-ffrancon by Llanberis and Llyn Cwellyn to the slaty region between Craig-Cwm-dulyn (Llwyd Mawr) and Mynydd Llanllyfni, and also to part of the slaty rocks in the valley north of Dolbenmaen that lies between Moel Hebog and Llwyd Mawr. In part this may arise from the fact that the strata of Lleyn are often coarser and much less affected by cleavage than the equivalent slaty strata of Nant-ffrancon, Llanberis, and of Rhos-lâs north-west of Craig-cwm-silyn. This may perhaps arise from the circumstance that the Bala beds of Lleyn were deposited in comparatively shallow water.

It is also remarkable that the narrow strip of Silurian slaty strata, only a mile and a half wide, between the Cambrian rocks of Llanllyfni and Craig-cwm-silyn, should to the west of Mynydd Mawr suddenly spread out so as to make four-fifths of the surface of the long and broad promontory of Lleyn. Immediately west of Llwyd Mawr, however, the country, including the western boundary of the porphyry south of Bryn-marsli, is entirely covered by glacial drift, and so sharp is the bend at the western angle of the mountain mass that Mr. Selwyn considered the western boundary of the porphyry south of Bryn-marsli, as a probable fault, especially as this supposition helps us to understand how the pent up Silurian strata that lie north-west of Llwyd Mawr may on the west side of the supposed fault suddenly

expand, and, by undulations of the strata, occupy so large a part of the promontory of Lleyn.

There can be no doubt that all the strata of Lleyn above the Arenig rocks belong to the Llandeilo and Bala series, or strictly speaking to the Bala beds of the adjacent parts of Caernarvonshire, and, indeed, as far as I know Wales, there is nowhere on a large scale any clear line of demarcation between the Llandeilo and the Bala beds.

The following lists of fossils drawn up by Mr. Etheridge and arranged from east to west according to the position of the places on the ground sufficiently prove this.

LIST of FOSSILS from the BALA BEDS of LLEYN, CAERNARVONSHIRE.

—	Species.*	Ynys-graled, 2¼ m. W. of Dolbenmaen.	Plas-hen, 1 m. N.W. of Llanystumdwy.	Pont-rhyd-hir, 1¼ m. W. of Pwllheli.	Pwllheli, Pen-'r-allt, and Tan-'r-allt.	Crugan, 1 m. N. of Llanbedrog.	Near Llanbedrog, on Road to Abersoch, W. of Mynydd Tir-y-Cwmmwd.	Boduan.	Garn-bach, Madryn.
CŒLENTERATA	*Favosites fibrosa*	—	—	2	2	—	8	—	—
	F. var. *Lycoperdon*	—	—	—	—	—	5	—	5
	F. var. *ramulosa*	—	—	—	—	—	12	—	4
	Petraia elongata	5	—	—	—	1	—	—	—
ECHINODERMATA.	*Encrinital* stems	—	—	—	—	—	—	10	—
ANNELIDA	*Tentaculites annulatus*	2	—	—	4	—	1	—	8
CRUSTACEA	*Calymene brevicapitata*	12	—	—	—	—	—	—	—
	C. Blumenbachii	—	—	—	—	3	2*	—	—
	Trinucleus concentricus	22	3	3	18	2	14	—	6
	Asaphus Powisii	5	—	1	—	1	2	—	—
	Illœnus Bowmanii	6	—	—	—	—	—	—	—
	Phacops conicopthalmus	6	—	—	—	—	16	—	—
	P. apiculatus	—	—	—	9	—	—	—	16
	Beyrichia complicata	2	—	—	5	—	—	—	14
	Homalonotus bisulcatus	—	3	5	11	—	8	—	10
	Cybele verrucosa	—	—	2	—	—	—	—	—
	C. rugosa	—	—	—	—	—	2	—	—
	Lichas laxatus	—	—	—	—	—	6	—	—
	Proetus latifrons	—	—	—	—	—	1	—	—
	Encrinurus punctatus	—	—	—	—	—	—	1	—
POLYGON	*Ptilodictya dichotoma*	—	—	—	—	—	1	—	—
BRACHIOPODA	*Orthis spiriferoides*	—	—	—	—	—	6	—	—
	O. elegantula	70	50	1	100	—	10	10	—
	O. flabellulum	—	—	—	—	—	—	100	—
	O. calligramma var. *virgata.*	—	—	—	1	—	30	—	—
	Leptœna tenuistriata	—	—	—	2	—	2	—	—
	L. sericea	14	—	—	17	—	—	4	20
	Strophomena grandis	35	—	—	—	—	—	16	17
	S. depressa	—	—	—	—	—	—	—	3
	Rhynchonella, sp.	—	—	—	—	—	—	1	—
	Lingula ovata	—	—	—	1	—	—	—	—
	L., sp.	—	20	—	—	—	—	—	1
LAMELLIBRANCHIATA.	*Ctenodonta lævata*	1	—	—	—	—	—	—	—
	C., sp.	2	2	—	2	—	—	—	—
	Clidophorus like *antiquus.*	4	—	—	—	—	—	—	—
GASTEROPODA	*Murchisonia scalaris*	12	—	—	1	—	—	—	—
	Pleurotomaria lenticularis.	—	—	—	1	—	—	—	—
	P., sp.	—	6	—	—	—	—	—	—
	Scalites, sp.	11	—	—	—	—	—	—	—
	Turbo crebristria	—	—	—	—	—	—	1	—
HETEROPODA	*Bellerophon Murchisoni, D'Orb.* (*striatus*, Sow.)	25	—	—	—	—	—	—	—
	B. bilobatus	6	4	—	8	—	—	—	—
	B. dilitatus	2	—	—	—	—	—	—	—
PTEROPODA	*Pterotheca*, sp.	12	—	—	—	—	—	—	—
		254	88	14	181	7	124	143	94

* The figures in the several columns express the number of specimens found in each locality.

The strata of the region of Lleyn already described somewhat vary in lithological character. Thus near Ynys-galed, the fossils were found in brownish yellow sandy beds exposed for a few yards, and surrounded by superficial deposits of drift sand and gravel. The fossils at Plas-hen were found in black rotten slate. At the school house Pwllheli the fossiliferous beds consist of a slaty sandy fine grained rock, and at Pont-rhyd-hir, west of Pwllheli, and somewhat higher in the series than the Pwllheli beds, the strata are black ferruginous slates which pass into gritty beds containing crystals of felspar. Some of the fossiliferous strata north of Pwllheli, are associated with the bedded volcanic ashes that strike north-east among the igneous rocks for several miles, which, in a general way, may be the representatives of some of the fossiliferous ashy strata of Snowdon and Moel Hebog, and indeed, many of the fossiliferous Bala beds of Lleyn occasionally resemble the sandy strata that lie below and encircle the interbedded porphyry of Moel Hebog. At Crugan near Llanbedrog the fossils were found in beds of blue shale with calcareous nodules, and west of Mynydd-tir-y-cwmmwd in beds of fine sandstone and arenaceous slate dipping northerly at angles of about 30°. At Boduan there are beds of coarse felspathic breccia passing rapidly into brown gritty sandstone. Fossils are very plentiful in the grounds of Boduan Hall. Round the felspathic porphyry of Garn-bach near Madryn there are blue fossiliferous shales, and a little further north sandy ferruginous slates, probably nearly equivalent to the beds at Boduan, and the same is probably the case with the beds at Ynys-galed.

Igneous rocks.—It now only remains to notice the igneous rocks of the promontory. These I shall describe from east to west. They are, with one exception at Pwllheli, probably of kinds usually called intrusive.

Criccieth Castle stands on columnar felspathic trap, and similar rocks are exposed by a partial removal of the drift at four neighbouring places, viz., Y-graig-ddu, Mynydd Ednyfed, Dynana, and Plas-hen. The rock of Mynydd-y-cennin, about a mile west of the porphyry of Llwyd Mawr, is quartz porphyry, similar to that of Llyn Padarn near Llanberis, and probably having a like origin, small granular crystals of quartz being set in a felspathic base.

The igneous rocks that give origin to the mountainous tract of the northern half of Lleyn, between Clynnog-fawr and Nevin stand boldly above the surrounding slaty region which is much obscured by superficial sands and glacial detritus. These bold hills give a distinctive character to the scenery, altogether different from the high scarped cliffs of Cader Idris and the Moelwyns, or from the peaks of Snowdonia or the long flat-topped undulations of Llwyd Mawr the Glyders, and all the mountains, so well from Beaumaris, that range from Carnedd Dafydd by Carnedd Llewelyn and Y-Foel-fras towards Conway. South of Clynog-fawr the hills around Clypiau, though often somewhat cliffy, have in general a rounded appearance, and the Rivals or Yr-Eifl further west though steep, have more of the aspect of obtuse cones than of sharp peaks, while towards Nevin the hills are lower and less marked in outline. Everywhere around these igneous masses the slaty rocks are much disturbed, and where the junction with the intrusive rocks is seen, they are altered or baked by heat. Far up the slopes and in among the upper valleys, long reaches of glacial drift penetrate into the recesses of the mountains.

Taking the whole district of Lleyn into consideration, for the most part they consist of rocks the basis of which is felspathic, sometimes forming ordinary felspathic porphyries, but very often intermingled with small specks of hornblende which, in some areas, occur so largely and is so well crystallised, that for a space the rocks consist of well defined greenstone or diorite.

The large elongated mass that, south of Clynnog-fawr, forms the hills of Bwlch-mawr, Y-Gyrn-ddu, and Moel Penllechog, shows several minor lithological varieties. On Bwlch-mawr the rock chiefly consists of white granular felspar with distinct isolated crystals and grains of hornblende, and these are sometimes set in a darker base of felspathic matter, and may then be called felspathic porphyry. On Gyrn-goch the rock is compounded mainly of small crystals of felspar, mingled with minute quantities of hornblende, and perhaps here and there with a little free silica, and on Moel Penllechog it is still more crystalline. In the same neighbourhood there is a small boss of well crystallised diorite three-quarters of a mile south-west of Clynnog-fawr, another of much larger size on Pen-y-gaer, south of Clypiau, and a third, still further south, on Carn Pentwrch near Llangybi.

This group of hills is separated from those of Yr-Eifl by the deep valley of Llanaelhaiarn. It consists of three distinct masses, separated by the narrow bands of almost black slates of Bwlch-yr-Eifl, and the beautiful little valley of Nant Gwrtheyrn or Vortigerns valley, or, as it is sometimes called Nant Gwaith-haiarn or the valley of iron-works, in which case, if iron ores were ever worked there, the black slaty rocks may probably belong to the Arenig beds. The magnificent cliff of Trwyn-y-gorlech overlooking the sea, is a quartz-diorite in so far that it consists of a mixture of granular and crystalline white felspar with numerous scattered specks of what may be hornblende. The high peak above the cliff, being the most northerly of the three picturesque peaks of Yr-Eifl, consists of the same kind of rock with perhaps not more than from a twentieth to a fortieth proportion of hornblende. It is largely quarried for paving stones. The rock that forms the coast cliff of Porth-y-nant is much the same, being a finely crystalline compound of felspar and hornblende sometimes in nearly equal proportions, while generally the felspar very much predominates. The slates between the mass and Craig-du may be seen apparently dipping towards or under its eastern margin, but possibly this is merely the effect of cleavage. The rock of the chief peak of Yr-Eifl, on which the trigonometrical station stands, is of the same general nature, and on the summit, about 1,600 feet above the sea, it is a fine grained felspathic rock, with a small proportion of disseminated hornblende, which in minute specks becomes more distinct when near the surface the rock is weathered. Occasionally it contains isolated narrow crystals of felspar (orthoclase?) about a quarter of an inch in length. The third peak of Yr-Eifl on which the great ancient walled fortress and town of Tre'r Ceiri* stands, consists of the same kind of rock, and this description is also applicable to Caer-gribin, Mynydd Carnguwch and the country further south.

A third great mass of the same kind forms most of the barren hilly country that extends from the coast-cliff of Careg-y-llam to Carn Boduan, near Nevin. On Careg-y-llam and Gwylfa the rock is a fine-grained diorite with small distinct crystals of felspar and hornblende, mingled in the proportion of about three-quarters of the former to one of the latter. On Mynydd Nevin and in the quarries near the road to Pistyll the rock is much more crystalline, the crystals of felspar being larger, the hornblende being sometimes distinctly developed and sometimes diffused as it were through the rock in specks and small blotches. Carn Boduan itself is formed of a bluish grey porphyritic felspathic rock with a very small proportion of hornblende. It weathers brown and yellow on the surface, but its inner fracture is blue. It is much jointed

* This old fort is very little visited, though it is by far the most striking hold of the kind that I have seen in any part of Britain, with its broad parapeted unmortared walls, its flanking defences and its numerous ruined houses, chiefly circular, enclosed within its bounds. Such fortifications in Lleyn and elsewhere are usually spoken of as *British*, meaning that they were constructed by the Cymry or Welsh. I believe that Tre'r Ceiri, and other fortresses of the kind in Lleyn, if built by a Celtic people, were the work of the Gwyddel, and were the strongholds of these ancient Gaelic inhabitants, during their gradual expulsion from Wales by the conquering Cymry encroaching from the west in the fifth and early in the sixth century. Even this, however, as far as I know, is only an assumption, and they may possibly be of older date than the first coming of the Gael, having at later times been used by that people and their successors.

and at its western base altered strata seems to dip at or under the igneous mass.*

The large mass, including Carn Madryn, that stretches nearly six miles north from Trwyn-y-mynydd, near Llanbedrog, consists of a kind of felspathic porphyry resembling that of Boduan. When a little weathered it shows pale yellow felspar crystals imbedded in a brown base, but when the fracture is fresh the colour of the rock is blue. The neighbouring small headland of Careg-y-defaid is also felspar porphyry charged with agate-like nodules. Near Pwllheli the rock of Careg-y-rimbill, better known as the Gimlet rock, is a beautiful and distinct diorite formed of crystals of felspar and hornblende in about equal proportions. It is much used as a building stone. The two larger masses on the coast east of Pwllheli are chiefly of felspar porphyry, that of Pen-y-chain being in places completely charged with agate nodules. The rock nearer Abererch is partly of the same general description with sometimes a small proportion of hornblende.

North and north-east of Pwllheli, as far as Plas-du, there is a broad strip of rock, in two places alternating with slaty bands. It hovers in character between an ill developed greenstone and a felspar porphyry. At the trigonometrical station it consists of large crystals of felspar imbedded in a hornblendic-looking base. Associated with this rock, about three-quarters of a mile west of Pwllheli, there occurs the only rock in Lleyn of an ashy or brecciated character. It is well stratified, and consists of small felspathic fragments, green grains, and broken crystals. Specks of slaty matter occur in it. A mass of igneous rocks of great size lies about half way between Llanbedrog and the western end of the promontory of Lleyn. It stretches from Trwyntalfarach near Llanfaelrhys to the Cromlech near Penllech, and is principally composed of varieties of greenstone on Penarfynydd, Mynydd-y-graig, and Mynydd-y-rhiw, but further north and west of Mynydd-y-rhiw, according to Mr. Selwyn, it passes into a kind of syenite, while some parts consist of the ordinary felspathic varieties of the district.

Between the neighbourhood of Llanfaelrhys and Porth-lleiddiad the igneous rocks consist of greenstone, the felspar and hornblende, well crystallised, being in about equal proportions. North of Porth Cadlan this patch is more than half a mile in width. A strip of well crystallised greenstone runs along the west side of Aberdaron Bay between Pen-y-cil and Porth-meudwy, and another small patch occurs on the north side of that little harbour.

Wherever any of these are seen in contact with the Silurian strata, the latter are found to be altered (baked) at the junction; but the change only extends a little way, and is not to be confounded with those greater metamorphic processes which, as in the neighbouring Cambrian rocks, are attended with a foliated re-arrangement of their constituents, and obliteration of their original lithological structure.

There is one circumstance connected with the promontory of Lleyn of a very marked kind. Standing on the highest peak of Yr-Eifl and looking to the north-east and south-west, the hills formed by the igneous rocks described, seem to form a great chain of *Puys*, beginning perhaps with the large boss of Mynydd Mawr, near Llyn Cwellyn, and stretching away to the south-west to Carn Madryn and Cefn Amwlch far down the promontory.

I have often thought that some of these dome-like masses may be parts of the deep seated melted material above which rose the craters from which the not distant lavas and ashes of Llwydmawr, Moel Hebog, and parts of the region of Snowdon were ejected, and if so it may have been that great part of the Bala

* This hill like that of Tre'r Ceiri is the site of a very large fort, an immense circumvallation sweeping round the slope of the hill and enclosing great numbers of the foundations of circular houses now mostly concealed among the thick woods, but better seen in an inner line of defence on the top of the hill, the walls of which are of unmortared masonry.

beds of Lleyn were also covered with similar accumulations of volcanic material that, excepting the small patch near Pwllheli, have since been removed by denudation.

From the same height, or from the rifled tumulus that in old times was piled on the highest part of Tre'r Ceiri, any one versed in the geology of the country, and capable of grasping its broader features, can, looking south-east and north, easily pass in review the whole physical structure of Merioneth and Caernarvonshire. Turning to the south-east the eye ranges over the broken Cambrian crags of Graig-ddrwg, Rhinog-fawr, and Llethr, the strata of which curving round towards the estuary of the Mawddach, plunge with the overlying Lingula and Tremadoc slates, beneath the lavas and ashes of the scarped cliff of the distant Cader Idris, and the marked line of volcanic rocks that forms the range of Aran Mowddwy. Thence striking north a long line of varied hills built of the same volcanic material forms the lofty ranges of the Arenigs and Moel Llyfnant, beyond which sweeping round to the west the steep scarps of the Manods and the Moelwyns complete the three sides of a magnificent amphitheatre of mountains of which the Cambrian dome forms the centre. Further north in one great panorama, a later series of Lower Silurian volcanic rocks form the loftier and even more picturesque coountains of Moel Hebog and Snowdon, the Glyders, Carnedd Dafydd, Carnedd Llewelyn and Y-Foel-Frâs, from whence the country in the far north-eastern distance seems to slope gently down to the comparatively minor hills of Penmaen-mawr and Penmaen-bach towards Conway. From the heights of Yr-Eifl the promontory of Lleyn, but for the chain of *Puys* looks like a mere plain, and away to the north, the whole of the undulating country of Anglesey in like manner seems almost perfectly flat with a few minor projecting hillocks, of which Holyhead mountain and Garn, near Llanfairyryhornwy, are the chief.

CHAPTER XXVI.

Anglesey and Holyhead.

General Description.—The chief stratified rocks of Anglesey and Holyhead are, in descending order,—

Permian,
Coal-measures,
Millstone grit,
Carboniferous limestone,
Old Red Sandstone,
Lower Silurian,
Metamorphic rocks, probably Cambrian.

Associated with these are hornblend-rock, greenstone, felspathic trap, elvan dykes, and granite.

The Cambrian rocks of Anglesey as a whole are much more metamorphosed than those of the neighbouring county of Caernarvonshire, and though in the north of the island a broad tract consists of thick bedded grits quite comparable to the Cambrian grits of Llanberis and Nant-ffrancon, yet by far the greater part of the so-called Cambrian area is formed of foliated rocks in various stages of metamorphism, and which in many places has reached that stage in which it can be called gneiss, and the whole in many ways resembles what I believe to be equivalent metamorphic strata on the north-west coast of Lleyn.

The Silurian rocks also occasionally pass into mica schist and gneiss, and both, but especially the Silurian strata, are in places associated with granite.

Under these circumstances it is not always certain that some of the Silurian may not have been included inadvertently among the so-called Cambrian strata; for by far the larger part of the metamorphic rocks of Anglesey apparently belong to the latter formation, and in mapping the country it was natural in doubtful cases rather to class the metamorphosed rocks with Cambrian than with Silurian beds.

The grounds on which the larger part of Anglesey is considered to consist of Cambrian rocks, will be best understood by comparing the following description with the 1-inch maps, Nos. 77 and 78, in addition to the map at the beginning of this volume.

It has been shown that where the Cambrian rocks approach the Llyn Padarn porphyry they are much altered, especially to the south-west near Glynllyfon. Close to the Menai Straits, near Bangor, the Cambrian rocks are often much altered in character, and if we prolong their strike and that of the overlying Silurian beds from Bangor under the Lavan sands to Beaumaris, and from thence to Glan-y-ffynnon at the east point of Red Wharf Bay, we find an association of strata similar to that of Bangor, black or dark bluish grey shales, resting on green, grey, and sometimes purple schists and grits, which though often much foliated and contorted, still bear as strong a resemblance to the

Cambrian rocks of Bangor as the latter do to those of Llanberis and the Ogwen, thus by insensible gradations uniting the whole.

The Silurian shales above adverted to, were, when the country was mapped, believed by Mr. Selwyn and myself to occupy underneath the glacial detritus the whole of the coast between Gallows Point and the Carboniferous Limestone tract in which are the well known quarries of Penmon, for, little more than a mile west of Castell Lleiniog, the shale is seen in a quarry near Bryn-poeth and in the neighbouring roads, where they consist of dark bluish grey or nearly black sandy micaceous ferruginous shales, with a few thin bands of grey felspathic sandstone, *and beds of pisolitic iron ore, in all respects resembling the iron ores of the Arenig beds of Tremadoc, Trwyn-y-tâl, and Cader Idris.* They dip north-westerly at angles of from 15° to 25°, but rise again with an easterly dip to overlie the metamorphosed Cambrian strata of Llaniestyn. Thence, to the north-west they are visible in the lanes as far as little cove on the coast below the ancient camp of Bwrdd Arthur, where they were described by Mr. Selwyn as "black shales with some purple bands lying *unconformably* on "older green siliceous schists." There also the shales contain the same kind of iron ore, and I cannot doubt that they are the actual equivalents of the Arenig beds of Cader Idris, Tremadoc, Bettws Garmon, Trwyn-y-tal and Llanengan, and also of the ordinary Arenig beds of Bangor, where as in Anglesey they lie directly on Cambrian strata.

Similar dark shales interruptedly skirt part of the coast of Red Wharf Bay at Tyddyn-y-waun, where the hard greenish grey micaceous and sometimes chloritic grits and quartzites of Mynydd Llwydiarth dip distinctly under them to the north-west. South-west, between Red Wharf Bay and the Holyhead road the country is very much faulted, but it is probable that but for the faults the stratigraphical relations, as regards unconformity of the Cambrian and Silurian strata, would be the same. On this supposition the narrow band of faulted Silurian rocks that runs from Red Wharf Bay to Tau-hirion, near Malldraeth Marsh, may be Arenig beds in part, though at the south end at Plas Berw they are known by fossils to belong there to the Llandeilo or Bala Beds (p. 225). It is thus probable that the broad band of foliated rocks that lies between the Menai Straits on the south-east and Red Wharf Bay and Malldraeth Marsh, form a faulted anticlinal curve of metamorphosed Cambrian strata, on either side of which the unconformable Arenig strata are thrown off, on the east and south-east between the Beaumaris country, Bangor, and Caernarvon, and on the north-west between Red Wharf Bay and Malldraeth Marsh.

The Carboniferous strata that cross the island together with the faults south-west of Red Wharf Bay, make it difficult or perhaps impossible to restore the original curvatures of the Cambrian strata as they existed before the unconformable deposition of the Old Red and Carboniferous series on the denuded edges of all the older strata. Disregarding for the present the long faulted patch of Silurian beds east of Pentraeth and Llanffinnan, we find

Of those known at Treiorwerth, all collected by the late Professor Henslow, one trilobite is as yet only known in the Tremadoc beds, and no Arenig forms have been found in this locality, and of the remainder six are Llandeilo and Caradoc species, seven of which range upward into the Llandovery strata. How it happens that the Nesuretus occurs in this neighbourhood is peculiar, but I would be sorry to pledge myself to the positive assertion of Tremadoc rocks being there because of one fossil, and also, as the fossils of the Llandovery beds of this locality are common to the Llandeilo and Caradoc rocks, it is clear that there is no necessity for assuming that true Llandovery strata are present at Treiorwerth.

The solitary fossil from Llanbabo also belongs to the Llandeilo and Caradoc strata.

While there is no doubt that the larger mass of Silurian strata in the central part of Anglesey is formed of Llandeilo and Bala rocks, the question arises whether or not some traces of the Arenig beds may not occur in contact with the metamorphic rocks that run from Llanfihangel and Llyn-treffwll northward. This question will be resumed further on.

The Old Red Sandstone of Anglesey lies unconformably alike on Silurian and Cambrian strata, and strikes in a long narrow strip from Dulas Bay, on the east coast, to Llangefni, where it is overlapped by the Carboniferous limestone, which, occupying a broad tract on the coast south of Lligwy Bay, strikes south-west and underlies the coal-field of Malldraeth Marsh. This Old Red Sandstone belongs probably to those upper strata of that formation, which some geologists consider as being more intimately related to the Carboniferous rocks than to the true Old Red series. The Carboniferous limestone in detached masses, also occupies part of the coast of the Menai Straits and the angle of Anglesey beyond Beaumaris, between Red Wharf Bay and the Outer Road.*

Beyond the granite, in the western part of the island, the boundary between the true Silurian and the presumed Cambrian rocks is often only approximate, being much obscured by drift. On the north-west side of the country coloured as Cambrian, near Pen-y-groes (between Llanfaethlu and Llanflewin), the broken rocks, full of quartz veins close to the junction, seem to indicate a fault; but if, as I believe, the foliation of these Cambrian rocks indicates the general dip of the strata, then near Treiorwerth and Presarfedd there is unconformable discordance between the Cambrian and adjoining Silurian strata. At Presarfedd, immediately east and north-east of Bryn-uchain, the Cambrian beds dip N.N.E., consisting of contorted foliated layers of quartz, felspar, and fine schistose matter. Twenty yards further east there are beds of unaltered Silurian slate dipping south-easterly at right angles to the dip of the adjoining Cambrian rocks, and in places at the base of these slates there are thin bands of fine slaty

* For fossils, *see* p. 258.

conglomerate, the constituents of which partly consist of small angular pebbles derived from the adjoining Cambrian strata. A little further south there is a field road leading from Y-Gat into the grounds of Presarfedd. Just at the boundary of the formations the Silurian slate is interstratified with grit and fine conglomerate, made of quartz, felspar, and fragments of gneissic rocks. On a geological horizon a little higher in the grounds of Treiorwerth, there are remarkable masses of much coarser conglomerates standing boldly up through the soil and containing pebbles of quartz, quartzite, felspar, gneiss, mica schist, and purple slate or schist. All these points seem to me to indicate that the Cambrian rocks of the region had already been elevated above the sea during the deposition of the neighbouring Silurian strata, and by their degradation partly yielded material for the formation of the Silurian beds.

Formerly I considered it barely possible that these discordant dips might indicate a fault, but on carefully re-examining the ground in 1876 I felt that the evidence, as above stated, indicates an obvious unconformity. When Mr. Selwyn mapped that piece of ground he also evidently held that opinion, for in a note written on the margin of a working map he states: "*Uncon-*" *formability of black shale on the old chloritic slates to be seen at* " *Presarfedd.*" In this case, then the strata lying unconformably on the metamorphosed Cambrian rocks may possibly be thin representative Arenig beds, but as yet no fossils have been found in them. This is a point of importance when taken in connexion with the relations of the Cambrian, Arenig, and other Silurian strata between Caernarvon, Bangor, and the ground north of Beaumaris. (*See* Chap. 27.)

The Millstone grit appears above the Carboniferous Limestone on the slopes skirting Malldraeth Marsh, and the overlying coal-measures rarely show themselves in natural sections from beneath the covering of peat, gravel, sand, and sheets of water that form the marsh.

The Permian strata are nowhere seen at the surface, but I inferred their existence from the lithological character of the red marls, sandstones, and conglomerates at the mouths of the coal pits, and from ascertaining that undoubtedly the coal-measure sandstones, shales, and beds of coal, crop upwards against the base of the red rocks which rest quite unconformably upon them. Coal-measures and Permian strata have both been preserved simply by the accident of the north-east fault that bounds the marsh having thrown them down so low, that fragments of strata that once, I have no doubt, spread over the entire island have been saved from entire denudation. Such is a general sketch of the stratigraphical relations of the rocks of Anglesey. The remainder is matter of detail.

Cambrian Rocks.—The Cambrian strata of Anglesey are nearly wholly metamorphic. The south-east part of the island is chiefly formed of a belt of metamorphic rocks from two to four miles wide, that strikes north-east from Newborough sands across the island to Beaumaris and Llanddona. They

are as thoroughly metamorphosed as almost any of the rocks in Anglesey. In the southern part of this area I have described them as "green, grey, and "sometimes purple, siliceous, chloritic, and micaceous schistose rocks, intensely "foliated in numerous small contortions,"* or, in other words, of siliceous mica schists, tinged with chlorite, or of thin layers of quartz alternating with grey and green micaceous and chloritic laminæ, the whole intensely contorted in wavy and twisted layers like many other gneissic rocks. The rocks occasionally consist of lenticular patches of quartzite, sometimes nearly white and traversed by veins of white quartz, as, for example, at the well-known China rock once quarried at Pen-y-parc near Beaumaris. In the same district, on and near the road that passes the cemetery on the way to the reservoir, the rocks are seen to consist of olive-green and occasionally purple and grey schists and fine grits, somewhat resembling those of Bangor, but more metamorphic in character. Near Llanfihangel Esgeifiog, north of the Holyhead road, by the marsh, the rock is in great part thoroughly metamorphosed into very hornblendic gneiss, consisting of quartzose and felspathic foliations intermingled with bands that may fairly be called hornblende rock.

In the south-east, as in other parts of Anglesey, the details of the structure of the Cambrian rocks constantly vary, and yet the whole remains so much the same, that minute descriptions of individual spots would convey little information. Foliation is often intimately connected with stratification. In certain unmetamorphosed rocks, probably under much pressure, at great depths, and influenced by long-continued heat, moisture, &c., the substances that formed the original strata became more or less decomposed, and rearranged themselves according to the chemical affinities of their constituents. This is one kind of metamorphism, and it will thus be understood how it may be easy to find pieces of clay, sandy shale, slate, mica-schist, and gneiss, not differing more on analysis than two pieces of gneiss do from each other. There seems, however, under such circumstances, generally to have been a tendency in the reconstituted substances to re-arrange themselves more or less in the direction of pre-existing planes. Judging by the relation of these rocks to the rest of North Wales, it is possible that to a great extent the metamorphism of the strata took place before the production of those larger contortions of the beds that induced cleavage; or otherwise, that over the area of what is now Anglesey the pressure that produced contortion of thick masses of strata was not so intense as in some other parts of Wales. In either case it might be probable that, though the traces of original bedding are very often obscured, the lines of foliation still approximately indicate the original direction of the layers of bedding, and the greater curves marked by the average direction of the foliated laminæ are in a large sense equivalent to ordinary curvatures of the strata.

Looked at in this way, notwithstanding minor contortions, the metamorphosed strata seem, on the whole, in this part of the island, to dip north-west and south-east, the central axis, as shown in the 6-inch section (sheet 40), lying somewhat nearer the Carboniferous limestone of the Straits than the coal-field of Malldraeth Marsh. Further north-east in the same general strike, it is again worthy of remark that, exclusive of minor contortions, the foliated strata lie in the form of an anticlinal curve, the axis of which is about half a mile north-west of Menai Bridge. From this point the foliated metamorphic strata dip south-east under the Straits, and by-and-by curving round dip easterly under the Arenig beds of Llanfaes and Bryn-poeth, while the less altered Cambrian rocks on the Caernarvonshire side, dipping in the same direction at high angles, are immediately overlaid by the same Silurian strata. The general effect of the north-east end of this anticlinal curve may indeed be traced in the sweep of the base of the Arenig strata northward from Beaumaris, a curve that is probably continued under Red Wharf Bay to join the patch that overlies the micaceous schists of Mynydd Llwydiarth. Beyond this the Silurian strata (much faulted however) are thrown in on the north-west side of the Cambrian axis, in that long strip which runs from the neighbourhood of Mynydd Llwydiarth by Plas Berw to Hendre-gadog on the east side of the Coal-measures, where they are cut out by the fault that throws the Permian against the metamorphic strata.

* Six-inch horizontal section, sheet 40, line 3.

Crossing the Carboniferous rocks of Malldraeth Marsh the geologist at once recognises the seeming equivalents of the metamorphic Cambrian strata nearer the straits, consisting partly of grey and purple, but chiefly of green schistose rocks, often chloritic, micaceous, and siliceous, with occasional patches of granular limestone and nests of jasper; the whole intensely foliated in numerous small contortions. The foliations probably indicate approximately the direction of the original lines of bedding, and if so the whole forms a basin, the layers undulating north-west between the Carboniferous limestone and the higher part of the river Cefni, and south-east from the river to what is believed to be a north-east fault that strikes through Tregaian. It may here be stated that the evidence of this fault consists simply of this, that along a straight line certain Silurian shaly beds dip towards and apparently *under* the metamorphic strata, which there is no good ground for separating from the Cambrian rocks on the other side of the coal-field, and the same may be said of the strip of rock that skirts the granite by Gwalchma and Llanbeulan towards the sea; but at the same time it cannot be denied that, though unlikely, it is *possible* the gneissic schists by the Cefni may be metamorphosed Silurian strata resting on an unaltered part of the same formation.

In Anglesey, north of the Holyhead road, the rocks between Caer Helen and Traeth-y-grubyn consist of green and purple schist, often micaceous, lying in wavy laminæ undulating north and south at angles rarely over 20°. The colours of the rocks are much more like those of the Cambrian than of the Silurian rocks of Caernarvonshire. About a mile and a half south-west of Llanfaethlu, at Porth-y-defaid, below Trefadog, there are green laminated schists with steatite, inclined south-east at 40°. North of Church Bay, towards Porth-y-dwr, the rock is principally a white or yellow felspathic schist, weathering brown, often wavy and serpentinous. In Church Bay part of these beds is soft and decomposing, and is associated with beds of quartz-rock and conglomerate. Between Church Bay and Carmels Point, at the north-west corner of Anglesey, I cannot better describe the rocks than by referring to my description of section No. 2, sheet 40 :—

"This section, from Carmels Point to the north shore of Church Bay, is little more than 2 miles in length, running from north to south across one of the most faulted and metamorphic parts of Anglesey. Some of the faults are easily seen on the neighbouring sea-cliffs, and others are inferred, for closely contiguous strata strike towards each other in a manner impossible without faults.

"On the north by the shore a few poor fossils, in irregular bands of limestone, clearly indicate the Caradoc or Bala age of some of the beds. The limestone is impure, inconstant, and of no economic value. Black wavy shales succeed these, faulted against gneissic rocks. The fault is a lode containing brown iron ore and copper pyrites. Through the foliated rocks, on Penbryn-yr-Eglwys, granite veins ramify in all directions, some of which may be distinctly seen on the neighbouring sea-cliff. Further south, in a broken country, narrow strips of black Silurian shale are faulted in between patches of metamorphic rocks foliated in wavy lines of quartz, interlaminated with green and purple gritty and schistose layers. On the south, towards Church Bay, the metamorphism is so extreme that in places the bedding has entirely disappeared, and without careful inspection and a knowledge of the whole neighbouring country, the rocks might be mistaken for igneous masses. There is no perfect security that the patches marked Cambrian in this section and their continuation southward to Holyhead Island may not be some part of the Lower Silurian strata metamorphosed, and the chief reason why they are believed to be Cambrian is that they underlie all the undoubted Silurian beds, and besides seem to bear a strong general resemblance to the metamorphic strata that lie on the north-west shore of the Menai Straits, which, as already stated, are the completely metamorphosed continuation of the less altered rocks of Bangor."

Among other points, it will be noticed that in this part of Anglesey the bedding and foliation cross each other. The bedding, though often very obscure, is nevertheless sufficiently plain to the practised eye to indicate this fact. The more definite lines pass in places into a species of waving imperfect

foliation that may have originally been cleavage, and the phenomena of this kind generally may be due to the circumstance that part of the country was contorted, compressed, and cleaved before the general metamorphism of Anglesey began; or, what is unlikely, that the metamorphism of the rocks of this corner is of later date than that of the country generally; or else that cleavage and foliation were in this and other cases produced simultaneously. It may be, also, that the foliation partly lies in original lines of false-bedding.

In this corner of the island these phenomena are common both to the undoubted Silurian shales and to the presumed Cambrian schists, which it is here impossible satisfactorily to separate, the Silurian rocks themselves being in places metamorphic. In Church Bay, where the metamorphism is extreme, joints are exceedingly numerous, and cross each other in all directions. The rock is extremely hard and homogeneous, the bedding obscure, and the foliation itself, which undulates north-westerly at angles of about 40°, is often indistinct. A little way in the interior, however, the wavy lines are sufficiently distinct, and the metamorphic nature of the rock becomes evident.

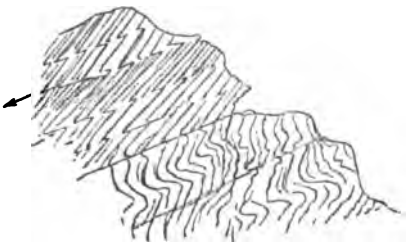
Holyhead Island.—Metamorphism.

Holyhead Island properly forms a portion of the Cambrian rocks of the west of Anglesey. Near its southern end, on both sides of the narrow strait that divides the islands, there are several large masses of serpentine, one skirting Llyn treflas, others bordering the sands of Tywyntrewan, another by the shore near Four-Mile Bridge, and the largest of all on Holyhead Island itself. The rock is of a mottled bluish-green colour, and capable of an excellent polish. It here and there contains talc and asbestos. Each boss as a whole lies in wavy contorted lines like the other foliated rocks of the country, dipping in the same direction, and conveying the impression, which is undoubtedly true, that they are metamorphic masses. This belief gains force from the circumstance that in undoubted schists near Tre-gela and Amlwch, far from the larger masses of serpentine, there are many thin wavy laminar lines of serpentine forming part of the ordinary metamorphic strata.

A fault traverses Holyhead Island from Borth-wen on the south-east to Gogarth on the north-west. The evidence consists in conflicting dips both in the interior and on the coast cliffs of Gogarth, Porth-y-corwgl, Bwa-du, and Borth-wen, where the break is plain. It is probably a downthrow on the east. On its eastern side, the strata, though foliated and contorted, are in general much less disturbed than on the west, where the contortions are often extreme. The lower strata in fact have suffered the greatest change.

Between Borth-wen and Bwa-du (near Rhoscolyn), the rocks chiefly consist of grits, including thick beds of quartz rock, occasionally interstratified with greenish-grey quartzose schist, and at Borth-saint there is a bed of "China stone," or very felspathic grit much decomposed. Stratification, foliation, and cleavage are, perhaps, often all and each sufficiently distinct, but again it is sometimes difficult to say if foliation and bedding coincide, or foliation and cleavage, or if the foliation has nothing to do with either. On a rock by the coast opposite Maen-y-fran there is the following appearance, the lines inclined in the direction of the arrow being bedding, and the twisted lines foliated

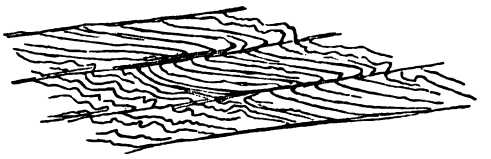
Fig. 78.



interlaminations of quartz and quartzose schist, which, it will be observed, except in one place, are always suddenly bent at the junction of the beds. This is common in Anglesey, and is not a mere change of angle, like that which often takes place in slaty cleavage when it passes from a fine to a coarse stratum. I am, however, inclined to think there is a connexion between them, and that the nearly straight lines suddenly and sharply bent at the junction of the beds and curving in others, may represent a species of cleavage and foliation in one, viz., that the pressure that under ordinary circumstances would have produced simple cleavage, has here, under the contemporaneous influence of metamorphic action, resulted in a complex foliation of the cleavage planes. At Bwagwyn there are similar appearances, the strata dipping E. 30° N. at 30°, and the foliated-looking cleavage N. 25° W. from 50° to 60°.

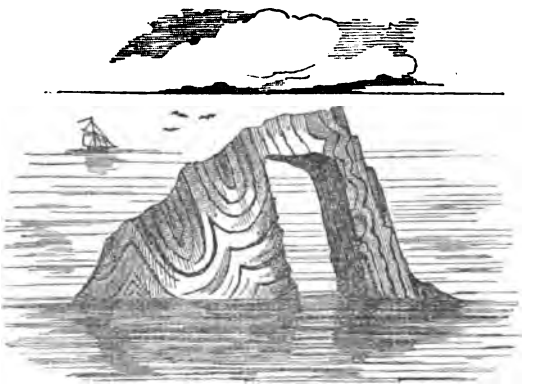
Between Bwa-du and Porth-y-corwgl, for several miles along the coast, the rocks lie on the east side of the fault, which here probably strikes across the bay. They consist of greenish-grey sandy micaceous schists, curving in low undulations, the layers rarely rising to angles of 30°, and between the misnamed Cromlech and Porth-y-post, they lie in waving lines at angles still lower. All of these rocks are, however, intensely foliated, often in small and sharp contortions, the angles of which, though acute, are so arranged that the entire lines lie at low angles, and may, as a whole, be said to be almost horizontal.

Fig. 79.



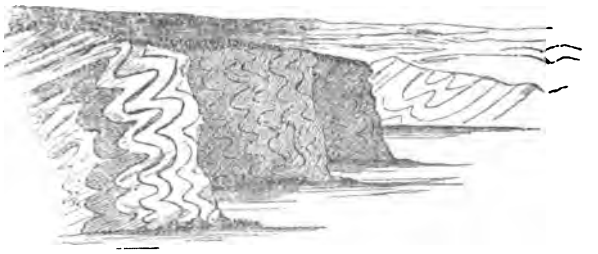
From Porth-y-corwgl to the South Stack and Gogarth, the rocks along the coast in a great degree consist of grits, mingled with occasional greenish-grey foliated micaceous schists. These grits, partly resisting denudation from their superior hardness, often stand out from the cliffs as little islets, characteristic of the west coast of Holyhead Island. Both islet and coast cliffs present,

Fig. 80.



perhaps, the finest cases in Wales of violently contorted strata. Sometimes the gnarled lines lie in rapid folds, running zigzag up the cliff, striking examples of which occur on the southern coast of Penrhos-filo.

Fig. 81.

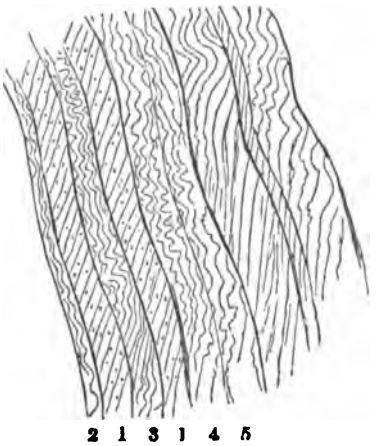


In others the strata as a whole run vertically from the bottom to the top of the cliffs, being at the same time bent backwards and forwards into a number of horizontal folds. Again, as for instance opposite the South Stack, the contortions, though still intense, have more gently flowing outlines.

As a whole, for about three miles south-east of the South Stack the highly inclined and waving beds *seem* to dip steadily north-westerly, at angles from 60° to 80°; yet so intense is the contortion that even then it is never certain that the outcropping edges of the beds may not be mere fragments of large curves, the sharply doubled up strata showing no sign of the curvature, for the tops of the bends have been cut off by denudation, while their bases lie below the sea. If the metamorphism of these and the Anglesey rocks be of Lower Silurian date, then they must have been subjected to two distinct forces incident to that epoch, one from below and local, during the process of metamorphic action, and a second and later force of contraction of part of the crust of the earth of more general application, by means of which all the Lower Silurian rocks of Wales were upheaved and thrown into broad undulations and often of rapid and intense contortions before the deposition of the Upper Silurian strata. These forces acting on rocks then buried deeply beneath great masses since removed by denudation, have produced in large areas in Wales a perfect slaty cleavage, and sometimes in places a vertical folding of the layers, as in Fig. 81, like many folds of paper crumpled in the hand.

Opposite the South Stack the contorted rocks in the upper part of the cliff consist of very hard quartzose grits, while below they are intermingled with schistose bands. Here the foliation of the rocks is worth special attention. In one of the curves, where the strata for a space dip south-easterly at a high angle, I observed first, that the distinct beds consist of sandy and schistose alternations, and second, that they seemed partly foliated and partly in lines without clear foliation. In the following diagram the sandy beds, No. 1, are marked with dots, and in these I saw no separation of distinct layers of

Fig. 82.



different mineral substances, such as would be called foliation in the sense in which it is used by Mr. Darwin, but only a sort of imperfect separation of material sometimes arranged in slightly wavy lines; while in the schistose beds complete foliation appears, with much twisting of quartzose and micaceous laminæ, each bed, however, still retaining its identity. In No. 2 these contorted laminæ follow the direction of the bed, and in Nos. 3, 4, and 5 they cross the beds, somewhat in the direction of the lines in the sandy beds, but (eliminating the contortions) at slightly different angles. The question is, Do these lines that cross the bedding represent both *cleavage* and *foliation*, or may they not rather represent *false bedding* and *foliation*? If the former, then cleavage and foliation were produced at the same time, and what relation do they bear to the larger physical disturbances of the country? The supposed imperfect cleavage in the gritty bands would be, according to the theory of Sorby and Tyndall, the result of mechanical pressure, which forced the grains of the beds to re-arrange themselves in certain planes. In such beds, the whole being quartzose, there were no ingredients present to separate into different laminæ, under the influence of metamorphic action; whereas in the schistose strata, originally, like other muddy shales, consisting chiefly of clay and finely-divided particles of silica, we have all the materials present, by a re-arrangement of which, according to their chemical affinities, metamorphic foliation might be produced. On the hypothesis now discussed, this metamorphism must have taken place either before or at the time that cleavage was being formed, both in the grits and associated shales, or if not, then metamorphism was effected at a later date where cleavage planes pre-existed. If the metamorphism was of Lower Silurian date, then it is not likely that the cleavage pre-existed that metamorphism, for it is almost certain that the cleavage of the Lower Silurian rocks of North Wales was a consequence of those contortions of the strata that preceded the deposition of the Upper Llandovery rocks. But if cleavage and metamorphism were contemporaneous, then the average difference of angle in the lines of foliation in the grits and schists may perhaps be comparable to that so common in ordinary *slaty* countries when cleavage planes pass from true slaty bands into beds of grit. If, however, cleavage preceded the metamorphism, then the foliated laminæ represent cleavage planes on which foliation with contortion of the foliated laminæ supervened. One other explanation remains, which is, in my opinion, the most probable, viz., that the foliated lines in the schist, and the unfoliated cross lines in the gritty beds, *lie in original lines of false bedding*, an observation also made in 1863 by Mr. Sorby,* for as it is certain that on a great scale foliation often coincides with stratification, so on a small scale it must often coincide with the minor planes of false bedding, the re-arrangement of material taking place in pre-existing lines.

East of the South Stack the rocks consist of "China stone," a felspathic grit, with contorted foliation dipping south at angles between 60° and 80°, and some of the beds of which consist of a kind of quartz rock. But by far the largest body of this latter substance in the island forms the eastern half of Holyhead Mountain. This mass extends along the north shore from the lofty cliffs of Gogarth to the point of Penrhyn-garw. On the west it is bounded by a fault, and on the south-east it dips at low angles and undulates beneath the beds of foliated micaceous schist that form the remainder of the island.

But though a careful examination of the boundary leads a skilled observer to the conclusion that the quartz rock dips easterly under the schist, on the mountain itself the bedding of the quartzite is either obscure or utterly obliterated. In the great quarries from which the quartz rock for the breakwater was obtained, no bedding is visible, while innumerable vertical joints seam the face of the cliff, while others much less close traverse the rock in all directions, so large and far apart that when blasted the rock sometimes fell in great masses. Where the joints are close the rock shivered into smaller fragments. The greater joints run approximately north and south and east and west, and it was by taking advantage of them in the construction of their galleries that as much

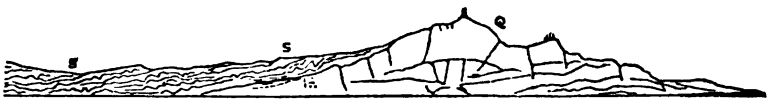
* Jour. Geol. Soc., vol. 19.

as 118,000 tons of rock have been brought down at a single blasting, and about 7,000,000 of tons were blasted and used in the construction of the breakwater. At the south end of the quarry there is a broad dyke of greenstone standing vertically, and very soft and decomposing, and close by, within a few feet of each other, there are two thin veins of the same material, which from the direction they take would seem to branch from the larger dyke at a point not far underground.

Now that the great breakwater has been finished for many years, the vast quarry once so thronged has a desolate aspect, and in spite of the intractable quality of a soil made of the waste of quartzite, vegetation begins to clothe the heaps of rubbish, while all the work now carried on, is the occasional extraction of a decomposing talcose white somewhat siliceous rock at the north end of the quarry, called "chert" in the lease, and used for or along with china clay.

A section across the mountain from north-west to south-east gives the following arrangement of strata:—

Fig. 83.



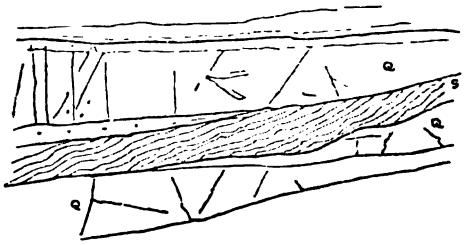
Q. Quartz rock.
S. Contorted foliated micaceous schist with numerous quartz laminæ.

Though invisible in the quarry, on the sea cliffs where well-weathered sections are exposed, the bedding often becomes distinct, and at the junction near Penrhyn-garw beds of quartz rock may be seen dipping easterly under contorted foliated schist on a low cliff on the shore.

Fig. 84.

Viewed as a whole, the bedding and foliation seem to dip in the same general direction, as shown in diagram No. 81, but the little foliated contortions are everywhere intense and rapid in the micaceous schist, while a careful study of the whole mountain makes it plain that the quartz rock lies in larger curves. Sometimes, however, as on the other side of the island, there seems only this connexion between them, that they dip on the whole in the same direction, the dip of the foliation in the schistose or gneissic beds being, however, somewhat greater than in the beds of quartz rock. Thus at Porth narmach, near the north end of the greenstone dyke, I observed the following appearance:—

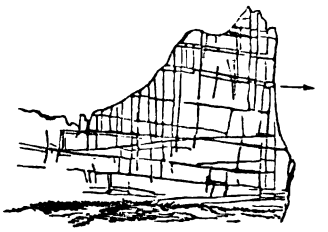
Fig. 85.



Q. Quartz rock. S. Foliated micaceous schist.

The larger strata are here lenticular and false bedded, and it may be that the oblique foliations in the schist lie in the minor planes of a cross stratification, commonly called false bedding. But there are other examples between this and the North Stack, where it is different. In one instance the undulating

Fig. 86.



micaceous quartzose strata dip slightly north-west with a little false bedding; and a vertical lamination that seems distinct from jointing, but is possibly allied to cleavage, passes across these lines. In another case, where the strata also lie nearly horizontally, I observed lines (not so close as those of good cleavage), which, nearly at right angles to the bedding, separated the rock into laminæ of different colours like an imperfect foliation, and at the same time passed right through the middle of some of the pebbles which it enclosed, as in Fig. 86. This, but for the different coloured laminæ, would look like jointing,

Fig. 87.

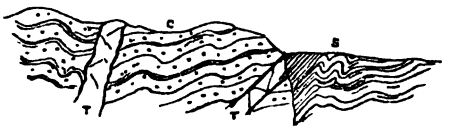
but at present I am unable to explain some of these phenomena, though I do not doubt that a long-continued and enlarged study of them over the islands of Holyhead and Anglesey might lead to important results.

Dykes.—Several greenstone dykes traverse the island in a north-west direction. One of these almost continuously crosses the general strike of the strata for about 7 miles from Cymmeran Bay to Porth-namarch. Four others lie between it and the west coast, running in the same general direction, which is also that of the fault which crosses Holyhead Mountain between Gogarth and Porth-y-corwgl, and all coincide more or less with the run of many of the larger joints. A short dyke lies to the north of the town of Holyhead.

The North of Anglesey.—From east to west between Carmels Point and Point Ælianus, nearly the whole of the north of Anglesey is coloured Cambrian. The inland part of this area is bounded on the south by faults, easily inferred by the discordant dips and strikes, both in the interior and on the coast cliffs, between the ordinary and black Silurian shales and the foliated schist and contorted grits of the north. This inference is further confirmed by the circumstance that a number of greenstone and felspathic trap or elvan dykes, south of Llanfechell suddenly cease at the presumed line of dislocation, which we should scarcely expect if the Silurian beds dipped under the foliated grits of Llyn-Felin-y-nant instead of being faulted against them. Grits and dykes are therefore suddenly cut off by the downthrow of black slaty shales, the northward continuation of which originally overlaid the grits. The geological date of these dykes is uncertain, but probably, like those of Holyhead, they are comparatively old; for it seems likely that they were intruded into fissures before the great fractures took place that threw the Silurian strata against what

seems to be a low part of the Cambrian grits, and that for the following reasons:—

Fig. 88.



S. Silurian shales.
C. Cambrian rocks.
T. Dykes.

A northward prolongation of the Silurian rocks S once covered the Cambrian grits C, which are pierced by the dykes T, in which case it would appear probable that the melted matter was injected into deep-seated cracks, which did not reach or at all events pass far into the overlying Silurian shales; for, if they ever pierced these shales, to or near the surface of the ground, it is improbable that each dyke should stop suddenly short at what is now the line of fault that cuts them off, seeing that the balance of chances must surely be much against all of these dykes originally suddenly ceasing in a line now coincident with the dislocation, not one of them having been prolonged beyond this line into the early continuation of those once unfaulted slates and grits that must now lie deep below the Silurian strata that form the country south of the fault.

The above-mentioned Cambrian grits are the lowest beds in this part of the island, and, though altered and sometimes foliated, yet lithologically they still bear much resemblance to the purple and green grits and slaty bands that form the Cambrian beds in Merionethshire and the lower part of the Cambrian rocks of Caernarvonshire on and near Llyn Padarn and the banks of the Ogwen. They occupy a large section of the country between Llanfairynghornwy, Llanflewin, and Bodewryd, and may be described as green altered grits interstratified with greenish grey and purple slaty shales, containing layers and sometimes beds of serpentine, examples of which occur between Llanfechell and Llanfairynghornwy at Tre-gela and Capel Caer-gors, another near Cefn-coch, and another in overlying strata at a chapel near Llanfechell.

The veined structure of the serpentines here also accords with the foliation, and the grits themselves are foliated in numerous small contortions of quartz alternating with a more sedimentary-looking material. The metamorphism increases in intensity in the lower beds towards the fault, where the elvan dykes are most numerous; but as the dykes seem only to alter the metamorphic strata slightly, in the manner of ordinary dykes, I do not believe that their presence is in any way connected with the metamorphism. The dykes, as already remarked, are altogether of later date, and from their direction may be of the same age with the greenstone dykes that traverse the Cambrian rocks of Llanberis and Nant Francon, one of which in the Penrhyn slate quarries contained a fragment of cleaved slate. They are, perhaps like the dykes that traverse the coal measures of Malldraeth Marsh, post-carboniferous, or possibly younger still.

With many minor curves, the low northern dip of the Cambrian strata is unusually clear in the broken low rocky hills, often almost bare of vegetation, that surround the lakes and pools of Mynydd Mechell, and though obscure in the softer shaly ground beyond, there is reason to believe that there is a general ascending section all the way from the fault near Llanflewin to the north coast by Cemmaes Bay and Llanbadrig, where some of the higher strata are clearly Lower Silurian, but other parts are of doubtful age, though apparently underlying them. On the north shore, between Yr-hên borth and Cemmaes Bay, the rocks consist of bluish-grey, green, and purple schists interstratified with each other, sometimes foliated with quartz liminæ arranged in wavy lines, which undulate at low angles to the north-east; and agreeing as they do with the true north-east dip of the grits above described, these wavy lines apparently coincide with the actual bedding of the strata. Striking to the south-east a part of them appear in the green and purple slaty shales that form the low soft country between Rhosbeirio and Cemmaes. The rocks still

further eastward, by Amlwch, are the general equivalents of the same strata, but as a whole they are much more metamorphosed. Their lithological character is generally similar to that which marks all the Cambrian rocks of Anglesey, consisting of greenish grey, green, and sometimes purple metamorphic slaty beds, with imperfect cleavage, and frequently intensely contorted foliation. This foliation consists of numerous quartz laminæ, strongly contorted, with layers of green and purple schistose matter, sometimes interlaminated with very thin layers of serpentine, proving in this neighbourhood the metamorphic origin of that mineral, even more than the patches on a larger scale near Llanfechell and Holyhead Island, in which, as already stated, the wavy lines are closely allied to those of foliation.

But in the Amlwch district this intense foliation only rarely coincides with the lines of bedding. Thus, near Point Ælianus, about 100 yards south of the lighthouse, I observed one case in which bedding and foliated lines seemed to agree, thus—

Fig. 89.

Between the lighthouse and the point there is a divergence in the lines, as in

Fig. 90.

Fig. 90, which at the point itself is increased, the strata dipping 35° N. 26° W., and the bedding is crossed at angles of about 63° to the horizon by lines, in one place slightly twisted, as in Fig. 91.

Fig. 91.

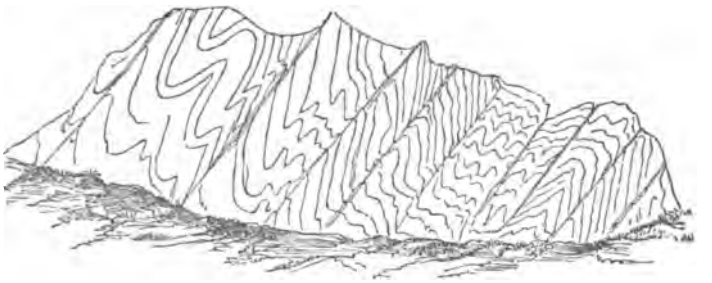
Near Bod Ednyfed-bach, about three-quarters of a mile south-east of Amlwch, in one of the bare rocky bosses that project through the soil, I observed the appearance presented by the following diagram:—

Fig. 92.

in which the straight inclined lines dipping at angles of 71° represent bedding, and the waving lines foliation, the quartz laminæ of which vary from a mere line to a quarter of an inch in thickness. It will be observed that these lines have a tendency to form an acute angle with the bedding, but are suddenly bent in a double curve just at the point where they pass from one stratum to another.

Between Amlwch and Llaneilian the following little section is exposed :—

Fig. 93.

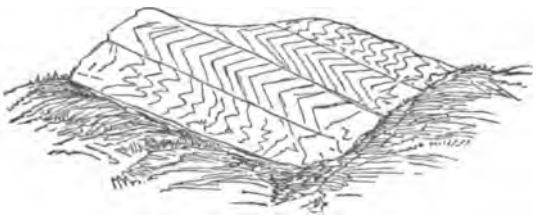


in which the foliation also has a tendency to form acute angles with the dip; while in another instance, near the lighthouse, intensely contorted and wavy foliated lines cross each other at much higher angles—

Fig. 94.

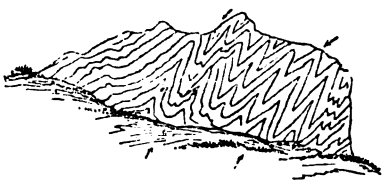
the contorted lines much resembling foliation, but in this case possibly indicate stratification. In the same neighbourhood, nearer the fault, in one instance where what I took for bedding dips at a high angle, the foliated lines highly contorted run, on an average, right across the dip, while again in the neighbourhood of No. 89 the foliations run zigzag right across the bedding, in the manner shown in the following diagram :—

Fig. 95.



In innumerable other cases the bedding is indeterminable, and nothing but the intensest foliation remains, although, from frequent experience, even then the observer is apt to consider that in certain cases the bends and twist are connected with, and perhaps indicate, obliterated lines of beddings which if present would run in the direction of the arrows on opposite sides of the woodcut No. 95.

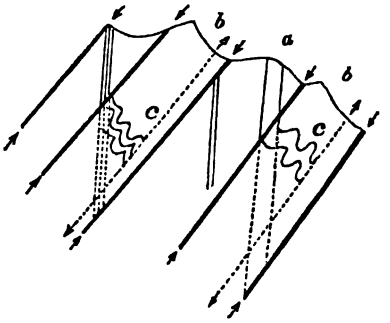
Fig. 96.



On the whole I believe that, as there is often a relation between cleavage and bedding in strike and dip, so there is often a connexion in strike and dip between bedding and foliation, for though the latter in Anglesey often crosses the former at some angle, the stratification as a whole dips northerly, and the foliations with innumerable twists seem in the main inclined in the same direction. In the cases cited also, it is exceptional to find what I have termed nearly straight foliated cleavage, but in the contorted examples illustrated by diagrams Nos. 90 to 96 there may still be a connexion between bedding, cleavage, and foliation, and the following explanation of the phenomena seems to me in many cases not unreasonable.

Suppose true slaty cleavage to cut in straight lines through beds inclined at any angle, and that afterwards foliation was superinduced in the line of the cleavage planes; then, while foliation was being produced by a chemical rearrangement of material accompanied by moisture and heat, the expansion produced by heat at great depths would induce intense pressure, one result of which might be, that such pressure, if exerted vertically from below, would in some instances compress the beds and reduce their individual thickness without obliterating the stratification, while *the foliatedcleavage planes also vertically compressed might be forced into contorted lines more or less across the planes of bedding*, as shown in the following diagram :—

Fig. 97.



Let the strong lines with arrows pointing at each other represent true beds, and let the fainter lines inclined at a much higher angle represent cleavage, which in its ordinary state would pass in straight lines from the beds *a* to the beds *b*, in which the cleavage planes are dotted; then if all the beds, while undergoing metamorphism, were compressed vertically by heat and expansion from below, the very compression of the beds *b* into minor thicknesses, say from the arrows that point ↓↑ to those pointing ↑↓, would contort the foliated cleavage planes by forcing them to occupy smaller spaces proportionate to the diminished thickness of the beds; so that the straight dotted lines, nearly vertical in the diagram, would become curved and twisted in the manner shown by the continuous lines *c c*.

When I speak of pressure from below by expansion, I consider it to be self-evident that the present surface then lay deep underneath a heavy pile of strata which has since been removed by denudation, and it was the weight of this great pile, opposed to the expansive pressure coming from below, *that, when the strata lay either flat or inclined, compressed them into thinner beds and contorted the foliations*, whereas when the strata stood vertically the *tendency of the pressure would be to thicken or increase the width of the bed* if indeed under such circumstances bedding could be detected at all.

It may thus happen that there is an intimate relationship between bedding, cleavage, and foliation; for it is known and has long been accounted for, that on a large scale the dip of slaty cleavage is now and then coincident with the bedding. In general, eliminating minor contortions, cleavage and bedding are inclined in the same *average* direction (though generally at different angles), on the opposite sides of the greater curves of disturbed strata, the explanation being that the pressure that produced the curvatures also produced the cleavage in parts of the formations that lay deep underground. Therefore it happens that if contorted foliation supervene, the wavy lines will also show a relation to the dips of the original lines of bedding.

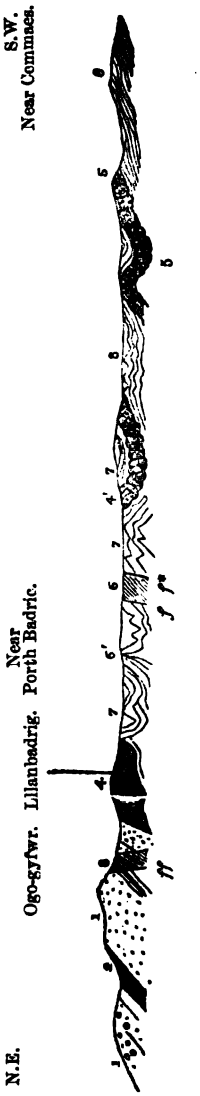
There are other cases, however, in which I believe (pp. 232, 233) that the planes of foliation coincide with true or with false bedding, perhaps only an imperfect cleavage, or none at all, having been present when metamorphism took place. In the case of foliated false bedding, the foliations might still be contorted, while the massive beds at certain angles of inclination would be compressed.

Cemmaes limestones, &c.—I shall now briefly describe the most northern part of the island, where the limestones and other rocks of Cemmaes Bay appear to be the highest beds of this area. The greater part of these are much contorted, highly metamorphosed, and greatly broken by faults. In Porth Badric and at Ogo-gyfwr, in the midst of these faults, there are two streaks of ordinary black Silurian shale, the most southern of which contains graptolites, but all the remainder of the strata seem to be unfossiliferous, and consist of bands of limestone, sometimes impure and siliceous, and banded with inconstant black shaly layers. The limestone is often highly crystalline, and seems to have been broken by intense pressure when deep under ground into numerous fragments, and re-cemented by calcareous veins. These bands are interstratified with beds of grey and blue altered gritty shales (sometimes nodular), and with quartz-rock. the whole being so excessively contorted and broken that "smashed" is the only word by which their appearance can be expressed. In Porth Badric itself there are great beds known as "China-stone," a kind of felspathic quartz-rock, which is traversed by many ferruginous veins, and in which the bedding is indistinct. These masses have been quarried and ground to mix with China-clay, and the substance is also said to have been used for the adulteration of guano.

Beyond the limestones, on the cliffs of Glocho and Hell's Mouth, there are beds of quartz-conglomerate and quartz-rock (in which there are "China-stone" quarries) dipping northerly at angles from 50° to 60°. The arrangement of the whole, faulted and contorted, about three-quarters of a mile east of Porth Badric, is shown in the six-inches to a mile section, Sheet No. 40. The section close to the shore is rather more complete, and the rocks lie nearly as shown in the following diagram:—

Fig. 98.

SECTION FROM GLOCHO ALONG THE EAST SHORE OF CEMMAES BAY.



No. 1 represents quartz-conglomerate and quartz-rock enclosing a band of limestone No. 2, immediately north of Ogo-gyfwr, where a band of black shale, No. 3, with gritty bands, is let in between two faults *f*, *f*; No. 4 is the band of broken limestone on which Llan-Badrig stands, which is repeated by a faulted anticlinal curve at No. 4′ where it again rises, overlaid by broken gritty shales, No. 7, in a contorted synclinal bend. No. 5 is another lower limestone, in the midst of similar contorted rocks 8 near Cemmaes, and the rocks in the bay marked Porth Badric consist of similar contorted gritty shales, quartz-rock, and China-stone, in the midst of which there are two bands of black shales, marked No. 6 and 6′, one of which, that between the faults *f*, *f**, contains graptolites. These shales, therefore, belong to Silurian strata, and it is possible that they may be let in by faults among altered Cambrian rocks; but I am more inclined to believe that the whole series, including the limestones, is Silurian, especially as five miles further west, on the coast between Porth-yr-ysgraff and Carmels Point, there are thin irregular bands of crystallised limestone containing Bala or Caradoc fossils mixed with foliated shale, under conditions somewhat similar to those at Cemmaes Bay. It is therefore likely that the limestones of Llanbadrig and all the associated rocks belong to the same series; and thus it happens that it is impossible precisely to determine on the north coast of Anglesey how much of the strata are of Silurian and how much of Cambrian age, more especially as we know that east of Amlwch and south of Llanerchymedd a considerable extent of Silurian rocks have been metamorphosed into gneiss and mica schist.

Silurian Rocks and Granite of the Middle of the Island.

The largest Silurian area of Anglesey lies towards the centre of the island (Map 78 N.W.), bounded on the north-west and south-east by the metamorphic rocks already described. Though somewhat obscured by drift, cleavage, and metamorphism, the strata as a whole presents an ascending series from the granite and fossiliferous grits of Llanerchymedd to the black slaty shale faulted against the Cambrian rocks west of Paris Mountain.

Granite.—The granite runs in a broad irregular belt, nearly 12 miles in length, across the island from the south-west coast near Llanfaelog towards Bodafon Mountain. Its greatest width near Llanerchymedd is under 3 miles. Where best developed it forms an ordinary granite, composed of quartz, felspar, and black and silvery mica (*see* 6-inch Section, Sheet 40, line 2), but in general it is a poor and rather coarse variety, the felspar indifferently crystallised, and the mica often absent, when it somewhat resembles parts of the kindred rock that lies between Bangor and Caernarvon.

The rocks surrounding and entangled in this granite are sometimes very perplexing, especially in its centre north of the Holyhead road, and on the eastern borders, where, owing to their metamorphic character, there is no sure way of determining whether the strata are of Cambrian or Silurian age. One of these doubtful masses north-east of the granite forms the quartz-rock of Bodafon Mountain, which, both in general structure and in the absence of distinct traces of stratification, closely resembles the quartz-rock of Holyhead Mountain. It probably lies in the centre of an anticlinal axis, for the undoubted Silurian rocks on the north-west dip from it, and some miles south of Bodafon the black Silurian shales of Llangwyllog overlie a southern prolongation of the rocks of the mountain. All along this side of the granite, towards Caernarvon Bay, it is more or less bordered by a belt of hard felspatho-siliceous-looking rock, sometimes faintly laminated or more clearly foliated, and rarely showing the bedding, which, as in the quartz rock of Bodafon Mountain, has often been obliterated, not by foliation so much as by a kind of induration of the fine amorphous siliceous strata. Near Bodwrog foliated portions of these rocks extremely metamorphosed are interlaced with the granite in the most perplexing manner; and a little further west, and immediately north of the Holyhead Road, there is a mass of altered rocks, about 3 miles in length, entirely surrounded by granite. Not that there is any definite boundary between them, for the foliated semi-crystalline rock is scarcely separable from and seems almost to melt into granite, rather than to skim its surface. Round Craig-yr-allor, about half a mile north of the turnpike road, the rocks often

pass insensibly into an extremely foliated hornblendic gneiss, similar to that near Caerwen and the Holland Arms, near the coal-field. In places the rock is so crystalline and hornblendic that it has often been mistaken for a mass of greenstone. An instance of a more complete metamorphism of the same nature occurs in the long line of highly crystalline black hornblende-rock that further north skirts the east side of the granite between Ynys-cynrig and Llanfihangel-Tre'r-beirdd.

On the west the demarcation between granite and gneissic rocks and unaltered strata is often equally obscure, so capricious are the ramifications and passages of the rocks into each other. South of Llanerchymedd it is on this account literally impossible to map the granite without including in it many streaks and patches of gneiss; and this is more the case where the granite is associated with felspathic sandstones than when it abuts on dark slate or shales, as if there were an intimate connexion both in the change of these felspathosiliceous rocks into gneiss, and also in the very fact of the appearance there of the granite itself in ramifying veins; for however closely the mass of granite may abut on black shales, it is rare in the island to find good granite veins intermingled with them. For instance, near Tafarn-y-botal, south-west of Llanerchymedd (*see* 6-inch Sections, Sheet 40, line 2), innumerable granite veins ramify among the gneiss, the metamorphism of the latter being so decided that granite and gneiss are inseparable. Again, further south round Llandrygarn and Llecheyn-farwy, much of the granite has a hornblendic character, and this along with gneissic streaks occurs so capriciously that both are not only inseparable from ordinary granite, but the geological mapper constantly feels doubtful whether or not the whole should be included with the gneissic rocks. It is thus impossible to work in this country without being constantly impressed with the idea that the granite and its veins themselves *are merely the result of a more thorough metamorphism than was attained in the production of the associated gneiss;* that is to say, *that absolute fusion of portions of the strata occurred under such conditions deep beneath the surface, and that reconsolidation of these fused portions by cooling produced granite.* If this be so, it will help to account for the difficulty of defining the limits of the streaks and patches of gneiss so intimately associated almost everywhere with the mass of the granite, and also with the fact, that the stratified rocks in places close upon its margin dip indifferently both towards and from it, not as they ought to do if the granite had been heaved up in the midst and had thrown off the beds on either side, but rather *as if part of the strata had been used up for the making of the granite itself.* In this case also there is an obvious reason why the general strike of the strata and of this granite is the same, to my mind far more satisfactory than to suppose that the strike has been produced by the upheaval of the granite, more especially as the strike of the Anglesey, Cambrian, and Silurian rocks form part of the great general system of contortion that affected North Wales before the beginning of the Upper Silurian period.

These opinions are not contradicted by anything known of other parts of the island where gneissic and granitic rock occur, and these I shall now briefly notice before proceeding to the stratified rocks. In the west of the island, near Llyn-trefwll (Map 78 N.W.), there is a small patch of granite, around which the Silurian rocks are much altered, being interlaced by numerous granite veins. North of Llanerchymedd and Llandyfrydog, amidst the Silurian sandstones and conglomerates, there are several small patches of rock coloured red in the map; they are hornblendic, and have generally been considered greenstones, but appear to me rather to be metamorphic, and somewhat of the nature of the hornblende-rock that skirts the granite on the east, and of the hornblendic gneiss of Craig-yr-allor W. of Bodwrog, more especially as they follow in the strike of some of the lines of granite that streak the strata west of Llanerchymedd.

West of Traeth Dulas there is a larger granitic mass, which stretches about two miles inland from the estuary. The granite is necessarily mapped chiefly as one mass, with several smaller patches piercing the associated highly metamorphic gneissic mica-schist on the south; but in reality they are inseparable from each other, so intimately do they seem to be interlaced. A better exhibition of similar rocks lies further north, between Paris Mountain and the sea cliffs of Llanwenllwyfo. Here also the lines on the map are barely approximate, it being impossible, in quarries and little road sections, to determine how

much is granite, and what are its relations to the metamorphic gneissic and quartzose rocks amid which it lies; but on the coast cliffs, where nearly a mile of section is exposed, it is more clear. At either side the metamorphic region is bounded by faults, as shown in the 6-inch section in Sheet 40, line 5, which crosses the country so near the sea that the rocks on the cliffs have been considered typical of those imperfectly illustrated in the drawing. The fault on the south is certain, black shales and thin grits being on the coast visibly thrown against the altered strata.

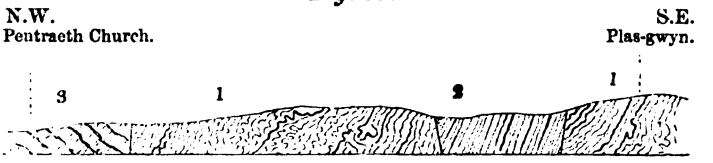
On the north the evidence of a fault, if less plain to the eye, is nearly as conclusive; for close up to the metamorphic rocks black slaty shales at high angles dip northerly, broken near their boundary, and seamed with veins of quartz; while immediately south of the boundary line, excessively metamorphic grits, also much broken and full of quartz veins, seem to strike at the slate at low uncertain angles. These beds are a kind of calcareous quartz-rock, confused, broken, and contorted, and among them veins of imperfect granite ramify. North towards Porth-lygan they pass into a kind of rough gneiss, the seeming product of metamorphosed grits, imperfectly foliated, and literally so squeezed and broken that the *smashed* fragments, as shown in section, scarcely dip steadily in any direction for a yard. On the north beach of Porth-lygan the rocks lie in very micaceous wavy foliations, dipping northerly; and in the hollow of the bay there is about 60 or 70 yards of black unaltered shale, without veins of granite, with a northerly dip of 60° or 70°. South of this there is a repetition of the same kind of micaceous schist or gneissic rock, mingled with quartz veins and highly metamorphic gritty bands, dipping northerly in undulating lines. Close to the outlier of Old Red Sandstone, seen at low tide unconformably lying on these rocks opposite Llanwenllwyfo, the micaceous and talcose schists are as red as blood, and are doubtless the metamorphosed representatives of fossiliferous Silurian strata. Most of the rocks are calcareous, and water percolating through them deposits patches of calcareous tuffa on the cliffs. Some of the more gritty gneissic rocks seem as if they had been altered almost to the point of fusion; and in them, but especially in the larger patches of the red flakey micaceous and talcose rocks, there are numerous small ramifying granitic veins; and some granitic masses, composed of quartz and felspar, look as if contained in and entirely surrounded by metamorphic rocks. These may be, as I once considered them, the ends of veins that branch from some larger mass hidden below, or else they were once connected with portions of ramifying veins above, but which have been, with portions of the strata, denuded away. But it seems to me quite as probable, if not more so, that they are simply portions of the rocks that have passed the limits of ordinary metamorphism and been converted into a kind of granite by a more complete fusion of material; and this is not unconnected with the circumstance that, while here the larger masses of associated black carbonaceous shale are almost entirely unmixed with granitic veins, both these and some of the smaller beds of black shale mixed at random in the schists seem, as a rule, to have been too refractory to admit of metamorphism, perhaps partly because of the absence of lime, and the bad conducting qualities of carbonaceous rocks, heat being certainly one of the agents of metamorphism.

Silurian Rocks.—The remainder of the Silurian rocks amid which the granites lie require a brief description. South-east of the great mass of granite in the middle of the island there is a belt of black slaty shales, nearly a mile in width, overlying the green and grey foliated grits of Llangwyllog. Although no fossils have been observed in them, there can be little doubt that they are of Silurian age, and like the rocks on the other side of the granite, belong to the Arenig, Llandeilo, and Caradoc or Bala series, curved, to judge from the dips, in the manner shown in the 6-inch section, Sheet No. 40, line 2, and apparently dipping towards and faulted against part of the great mass of foliated Cambrian rocks near the river Cefni that lie north and west of the coal-field.

East and north-east of the coal-field undoubted Silurian rocks again appear. It has already been stated that Arenig rocks strike from Bangor under the Lavan Sands to Beaumaris, and partly concealed by deep drift encircle the north end of the metamorphic Cambrian strata to Red Wharf Bay, where they are seen to be cut off by a fault which throws them down on the east against a part of the gneissic rocks below Mynydd Llwydiarth. From the middle of

Red wharf Bay to the south-west the strata are much dislocated; and if it be considered that the relations of the Cambrian and Silurian rocks are here too obscure to admit of certainty in the lines of fault that seem to affect them, the existence of several large and well defined north-east faults within a narrow area is rendered certain by the manner in which the Carboniferous Limestone and Coal-measures are affected between Red Wharf and Malltraeth Bay. It appears as if between two of this set of faults the black shales east of Pentraeth were let down between the metamorphic rocks in the manner shown in the accompanying diagram.*

Fig. 99.



1. Metamorphic rocks. 2. Silurian shales. 3. Carboniferous limestone.

This Silurian band strikes southerly, and between Plas Penmynydd and Plas-Berw it is faulted against the Carboniferous limestone, and further south, at Hendregadog, against the coal-measures. At Plas-Berw its relation to the Carboniferous and metamorphic rocks is shown in diagram No. 106; but whether so far south it is faulted against or regularly overlies the foliated rocks on the east is somewhat uncertain.

Probably most of this strip belongs to the Llandeilo and Bala beds here dovetailed by faults into metamorphosed Cambrian strata. South of Plas-Berw, where the rocks consist of shales and interstratified grits, Llandeilo or Bala fossils were obtained—*Orthis calligramma* and *O. elegantula, Favosites fibrosa, Encrinite stems, Asaphus Powisii, Calymene brevicapitata,* and *Phacops apiculatus.*

It has been already mentioned that beyond the central granite near Llanerchymedd the dips of the Silurian rocks present an ascending section from south to north. The quartz-rock and foliated schists of Bodafon Mountain and its neighbourhood is overlaid on the north-west by dark grey or black Silurian shale and grits, which stretch from thence along the borders of the granite to the south-west coast by Llyn Faelog and Cymmeran Bay. As a whole, these beds dip north-westerly from the granite at angles between 30° and 60°, and in most places yield to careful search a considerable number of the ordinary Bala fossils. It will be observed that north-east of the sands of Tywyn-trewan the recognised Silurian rocks lie in a narrow band from 1½ to 2 miles wide, between the granite and the foliated rocks of the west of Anglesey. As a general rule, on the south-east, east, and north-east of these rocks, undoubted Silurian beds dip from the metaphoric rocks thus distinctly overlying them, and from the ascertained dips there is every appearance of a synclinal curve of the Silurian strata betwixt the foliated schists of the west of Anglesey and the granite, but the boundary is in places so much obscured by drift that there may be unknown faults, otherwise the strata in contact with the schists may possibly consist of Arenig beds.

Where the Silurian rocks broaden, in the central part of the northern half of the island, the more gritty fossiliferous beds of the series is about 2 miles wide near Llanerchymedd, dipping mostly north-west (*see* Map, and Section, Sheet 40, line 2). By degrees the grit bands become fewer, and the strata pass into black slaty shales, shown in a considerable number of small exposures west and north of the river Alaw, these sections being, however, often so small and unsatisfactory that it is impossible always to determine whether the observed planes indicate true bedding or cleavage. In one little quarry, however, by Rhosganol near Llanbabo, it is evident that in the case of homogeneous slaty rocks the observer might easily be deceived, for in a space of about 50 feet the presence of a very thin band or of thin bands of grit revealed the excessive contortion of strata, in a manner impossible to guess at in the cleaved slaty rocks, where all is equally fine and of one colour. But for

* *See* also Horizontal Sections, Sheet 40, line 6.

Fig. 100.

the grit, the cleavage might here readily be mistaken for bedding. Notwithstanding these perplexities, enough of evidence, however, remains to show that the average dip of the country is towards the metaphoric foliated grits of the north of the island, and for reasons already stated, it is believed that they do not pass under, but are faulted against them in the manner shown in the 6-inch section, and in fig. 87, p. 236.

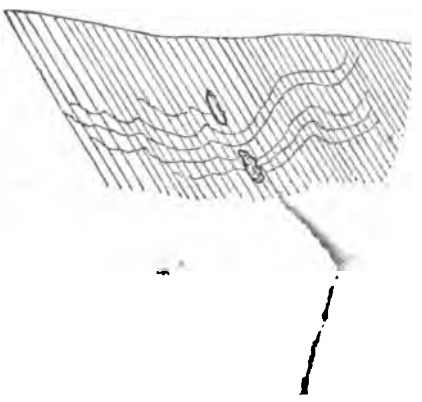
Between Llanbabo and Carmels Points, at the north-west angie of the island, a band of Silurian black slaty shales, grits, and conglomerates, about 1½ miles wide, strikes north-west between the altered strata. They are often ferruginous; and frequently recurring adverse dips and strikes in rocks of different kinds, in close proximity with lodes of quartz, often give fair evidence of faults, which, to a careful observation, are especially evident round Garn and Llanfairynghornwy Mountain, and in the intricately broken rocks of the coast cliffs between Yr Henborth and Church Bay.

Some portions of these Silurian rocks are partially foliated in numerous small contortions as, for instance, in one case by a footpath near Llanflewin, and the imperfectly granitic veins and dykes between the neighbourhood of Mynachty and Yr-ogo-'r Arian, seem connected with Silurian and possibly with Cambrian strata. In the concretionary half-crystalline limestone of Porth Newydd, near Carmels Point, as already stated (p. 229), the Caradoc or Bala age of the rocks is, however, shown by the few fossils found there.

In the north-east of the island undoubted Silurian strata occupy a broader tract on the shore between the Old Red Sandstone on the south, and the foliated rocks of Point Ælianus. These have been partly noticed in describing the granitic rocks that lie among them.

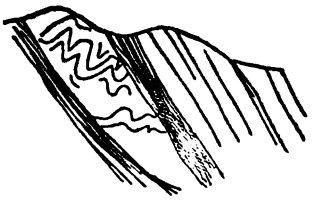
It has been already stated that black shales, interstratified with thin grits, are faulted against the gneissic rocks on the north shore of Dulas Bay. Similar slaty beds with waving dips, and disturbed by the intrusion of a branching greenstone dyke, continue south along shore to the estuary of Traeth Dulas, near which the dip is obscure, except in so far that the neighbouring ground seems to indicate that it is contorted, with average dips to the north, the Old Red Sandstone lying highly unconformably upon it. On the north side of the metamorphic rocks the strata also seem faulted against them. They consist of grey and black slates, dipping northerly at angles of from 70° to 80°, if the lines of apparent dip are to be trusted, for the layers are partly foliated with wavy quartz laminæ. On the north side of Porth-y-gwichiad the rocks are sometimes puzzling and in the very last geological excursion made by Sir Henry De la Beche, I pointed out phenomena to him, which strongly attracted his attention. The strata there consist of soft dark blue or black slaty shale, with nodules and short thin nodular bands of grit lying in planes which, were they absent, the observer would not know whether to call planes of bedding or cleavage. But even their presence does

Fig. 101.



not remove the difficulty, for when closely examined the highly inclined lines are seen to be traversed by numerous finely contorted lines, which, but for the gritty nodules, would be considered as obscure lines of bedding. In the highly inclined lines there is also occasionally a feeble separation of different coloured laminæ, and also faint lines of foliated quartz; and this renders it still more doubtful whether or not the concretions and thin lenticular quartzose bands may not also be arranged rather in lines of cleavage than of bedding, this result being due to some peculiar influence of metamorphism. On the north side of the bay the shales are light green and brown, and contain patches and veins of quartz and wedges of quartz-rock with a northerly dip, in which are foliated lines, thus,—

Fig. 102.



Between Dulas bay and Porth-y-corwg the strata consist of bluish-black slaty shales, interstratified with grit and beds of rudely cleaved conglomerate, the pebbles of the latter being often set in a rough slaty matrix. They are sometimes but little waterworn, and are mingled with blocks and nests of impure limestone, sometimes a few inches, sometimes more than a foot in diameter. In these no fossils were observed. Their general arrangement is shown in the horizontal 6-inch section, Sheet 40, line 5, and cleavage and dip nearly coincide. From their position it is evident that they belong to the same set of conglomerates and grits that form bands in the Silurian rocks further west. As a whole, these strata are constant, though the individual beds are scattered and irregular. The pebbles of the conglomerates are sometimes 6 or 8 inches in diameter, and, taken from different places at random, consist of white quartz, grey quartz-rock, mica slate, green schist, jasper, purple slate, a granitic rock of quartz and felspar, with sometimes a little mica, blue felspathic trap, dark green hornblende rock, and chloritic schist. Most of them are rounded, but the green schistose pebbles are generally angular. It is worthy of remark that this assemblage is much the same with that found in the Cambrian conglomerates of Llanberis, and, though on a hasty examination it might be supposed that the metamorphic and granitic pebbles of these conglomerates might be derived from some of the Anglesey rocks themselves, it is evident on reflection that such was not the case, the metamorphism of the Anglesey rocks having taken place after the deposition of the Lower Silurian strata.

A greenstone dyke, formed of felspar and hornblende in about equal proportions, pierces the strata of the coast, running slightly across the beds, and several other patches occur further west. In Porth-y-corwg the fault occurs which throws these strata against the more metamorphic rocks of Point Ælianus. The grits and conglomerates alternating with slaty bands, here shows the dip of the undoubted Silurian rocks to be northwards at a high angle, and striking as they slightly do against the foliated rocks that form the north side of the bay, the fault may be considered certain. West and south-west of this point, towards Paris Mountain, this fault is continued, and forms one of a set of dislocations, which, judging by similar conflicting strikes, seem to indicate that the black shales and conglomerates and the more foliated rocks are dovetailed among each other in an intricate manner, although this confusion may be partly due to the effects of mere metamorphism, which between Paris Mountain and Amlwch is so powerful that south-east of the town the rocks almost appear as if streaked with bands of felspathic trap, while a similar mass by Carregwinllan is almost identical in structure with the rocks of Paris Mountain.

Paris Mountain.—The well-known rocks of Paris Mountain consist of two principal hard bands, that on the south being separated from the granitic and gneissic rocks by a narrow belt of black slaty shale. Between them is another band of very black shale containing graptolites, and in the midst of this, between the hard rocky masses, lay that great bunch of copper pyrites which, except in certain minor branching veins, has been almost entirely quarried away. It is a difficult matter to name or decide on the origin of the hard masses that are associated with these slaty shales. Sometimes they almost look like interbedded felspathic traps, and at other places they are much more siliceous and break with a flinty fracture like hornstone. Sometimes they have a sedimentary aspect, and are streaked with blue, looking as if, when deposited, the rock had been slightly intermingled with fine dark-blue mud. The whole is more or less rusty-looking or ferruginous. From a hand specimen, or even on the ground, its bedded look might almost incline an observer to class it with the more finely bedded felspathic ashes of Caernarvonshire, and in other spots it might be mistaken for the unsedimentary felspathic trap of Snowdon, and again in part it resembles that felspathic substance that near Penmachno enters into the composition of large lodes. I have, however, no doubt that these hornstone-looking thick bands are merely lenticular metamorphic masses, about two miles in length, altered from an original argillaceous rock, in which, in a state of very fine division, materials abounded from which a hard siliceo-felspathic-looking rock was produced by some process of metamorphism, the precise nature of which I cannot attempt to indicate. I do not doubt, however, that this metamorphism took place contemporaneously with that of the neighbouring Silurian rocks, that are associated with lines of granite, and stretch to the sea-coast north of Dulas Bay. If so, the alteration of the strata of Paris Mountain was effected deep underground, probably under the influence of heat and moisture, the altered strata having since been exposed by denudation. The fracturing of the country by faults is clearly of much later date than this early metamorphism, and the cross faults and copper lodes of the mountain belong to that later period; but running, as the great original deposition of copper pyrities did, in the line of strike of the slaty band between the hard rocky masses, it is by no means certain that the ore may not have been introduced in among the strata in solutions some of which helped to produce the metamorphosis of the large hard rock-bands, and which seems to have impregnated the original sediment with an extra amount of silica.

CHAPTER XXVII.

ANGLESEY CONTINUED. THE GEOLOGICAL RELATIONS OF THE ARENIG BEDS, &C. WITH THE CAMBRIAN AND SILURIAN ROCKS OF CAERNARVONSHIRE.

I have now described the Cambrian and lower Silurian geology of Merionethshire, Caernarvonshire, and Anglesey, and before going further it is desirable to sum up some important questions respecting the circumstances that attended their deposition.

In Anglesey some of these questions at first sight appear to be very much complicated by metamorphism of the strata, for though it is easy to decide that the dark slaty shales and fossiliferous grits are partly of the age of the Arenig and partly of the Llandeilo and Bala beds, and though I have no doubt that by far the greater part of the foliated rocks are of Cambrian date, yet the lithological limits that divide them are sometimes arbitrary and obscure, and in a few cases liable to doubt.

The merely stratigraphical views already advanced respecting Anglesey, in the main agree with those arrived at many years ago by Sir Henry De la Beche, Mr. Smyth, Mr. Selwyn, and myself. Taken in connexion with the strata of Merionethshire and Caernarvonshire, there are however peculiarities in that part of Caernarvonshire that borders Menai Straits and also in Anglesey that now deserve special attention.

In the district of Merionethshire west of the Upper Silurian rocks, there is a descending section of about 7,000 feet in thickness across the Bala and Llandeilo beds down to the Arenig slates, at or near the top of which lies the Pisolitic iron-ore, while at their base lies the bed of grit so frequently mentioned in this memoir. Close above this horizon those great accumulations of volcanic ashes and lavas occur so well seen on the flanks of Cader Idris, the Arans, Arenigs, and Moelwyns, while further north in Caernarvonshire, on the geological horizon of the Bala Limestone and the strata close below, there comes on a second and younger great volcanic series, of which the ashy peak of Snowdon forms the culminating point, itself the equivalent of the Bala Limestone.

In Merionethshire, between Cader Idris and the country of Ffestiniog and Portmadoc, the Menevian, Lingula, and Tremadoc beds cannot be estimated at less than from 5,000 to 7,000 feet in thickness. But much of this great array vanishes as we pass the range of Moel Hebog, Snowdon, and Carnedd Llewelyn. There the topmost strata of the higher volcanic rocks represent the Bala Limestone, and beneath the lavas and ashes of Snowdonia no trace is found of the older great volcanic series of the Arans and the Moelwyns, while all of the Lower Silurian sub-formations that cover so much of the vast area of Merionethshire and Caernarvonshire south and east of Snowdon, are apparently packed into the narrow space of about a mile, that, in the Pass of Llanberis, lies between the felspathic lava of Garn and the Cambrian grits of Llyn Peris, and of two miles or less in the neighbouring valley of Nant Francon. The thick fossilferous grits also of the Bala beds of Dolwyddelan, Moel Siabod, Cynicht, and Moel Hebog, have dwindled to a few hundred feet of strata that lie amid the lower felspathic lavas of Snowdon and Carnedd Dafydd, and all the slaty rocks that lie below these in the Passes of Llanberis and Nant Francon, and overlie the Lingula flags, have as yet yielded no fossils of any kind. There is, however, a north-east fault which traverses this part of the Silurian region, and the thickness of the slates may originally have been somewhat greater than it now appears to be.

The fine muddy lithological character of these slaty rocks, seems to indicate that they were deposited in deeper water than the coarser sandy sediments of the same age further to the south and east, where the occurrence of these coarser strata may possibly be connected with the volcanic outbursts of the time having partially elevated the sea-bottom in the region where the fossiliferous sandy strata are now found. The intense cleavage of the slaty rocks in the Passes may also help to account for the absence of

discovered fossils, and may also tend to conceal contortions and tend to exaggerate the thickness of the slate.

This apparent absence of fossils being the case, the question arises what is the age of the strata between the fossiliferous sandy beds of Snowdon Y Garn and Carnedd Dafydd, and the Lingula beds of Llanberis and Nant-ffrancon.

There can be no doubt that a large part of these slaty strata on either side of the Passes, and also of the valley of Llyn Cwellyn, are of the age of the Llandeilo and Bala beds, and on the evidence afforded by the pisolitic iron-ore of Bettws Garmon, there is every reason to believe that the lowest portion of them chiefly or altogether belongs to the Arenig slates, which there lie close above the uppermost Cambrian grits. Above the Lingula grits of Elidyr-fawr and Nant Francon, this iron ore has not been discovered and probably does not exist. If, as seems likely, some part of these strata are true Arenig beds, the next point is, do the Tremadoc slates exist anywhere in this area between them and the undoubted Lingula beds.

In 1875 with Mr. Homfray and Mr. Etheridge I re-examined the Lingula beds of Marchlyn-bach and Marchlyn-mawr and the overlying strata of Bwlch-y-brecan west of Nant-ffrancon. Above the Lingula grits there are first darkish blue slates, which when split sometimes show brown stains on the planes of cleavage or bedding whichever they may be. These Mr. Homfray at first thought might represent the black slates that form the upper part of the Lingula flags in the Tremadoc country, and again that they or an upper part of them, may be the Tremadoc slates, but in the absence of fossils, and in the fact that in lithological character they are much less massive, and otherwise have little or nothing in common with the proved Tremadoc slates, it may be dangerous to assume their identity. South-east of this on the eastern side of the fault that crosses the ridge between Bwlch-y-brecan and Foel-goch, we suddenly come on very light bluish-brown slates which have been already described (p. 164).

Turning to the Lingula beds, we find that instead of being between 3,500 and 4,000 feet thick, as they are between Port Madoc and Ffestiniog, in the Passes of Llanberis and Nant Francon they are barely 2,000 feet in thickness. Taken in connexion with other proved phenomena this circumstance seems to me to be of much significance, and probably to indicate not so much the thinning away of the strata, as *an actual overlap by the Arenig beds across the underlying Tremadoc slates and part of the Lingula flags.*

In the Portmadoc country there are about 6,800 *feet of strata between the base of the Arenig beds and the Cambrian grits,* which strata consist in descending order of three subdivisions, Tremadoc, Lingula, and Menevian beds. At Bettws Garmon, *between the pisolitic iron-ore at the top of the Arenig slates and the topmost bed of Cambrian grit, there is only room at the outside for* 1,100 *feet of strata,* dipping at an angle of 55°, which is probably above the average, and even if we assumed the strata to stand vertically

(which is not the case) the total thickness would only amount to 1,400 feet. But it must be remembered that the pisolite always lies at or near the top of the Arenig beds, which strata near Portmadoc are 800 feet in thickness below the lowest bed of felspathic lava, and if we must include some of the slaty interstratifications connected with the volcanic series, we get a thickness of almost 1,400 feet. Under these circumstances, *I dare not assume that a small fraction of the strata between the bedded iron-ore and the Cambrian grit of Bettws Garmon represents three subformations* 6,800 *feet thick near Portmadoc, or even the* 2,000 *feet of Lingula beds in Nant-ffrancon and on Elidyr Fawr* only a few miles distant. Other stratigraphical phenomena bear still more strongly on the question.

I have already described the Cambrian rocks and the overlying Arenig slates of Bangor and Caernarvon (chapters 22, 23, 24). If any person desires at one view to see their relation to the rocks of Anglesey, let him from Beaumaris ascend to the top of the knoll above the old quarry of the "China rock" at Pen-y-parc, 310 feet above the sea, and from thence, looking to the north and south-west, he will get a view typical of great part of Anglesey. Everywhere lumps of rock, gnarled and somewhat metamorphosed, stand out bare and barren or covered with gorse amid the broader grassy patches of the soil which lies on the softer glacial drifts that surround them, and all along the broken table-land that overlooks the Straits towards Menai Suspension Bridge, there prevails the same kind of rough scenery of rocky knolls and grassy sinuosities winding in and out among them, the average height of the whole being only from 200 to 300 feet above the sea. Then let him turn his eyes towards Bangor, and in the broken hillocks behind the town, and in the pleasure grounds above the railway tunnel, he will see the precise counterpart of the Anglesey scenery, the same general height, and the same rough knolls formed by rocks, often less altered but of the same general character as those that form the knolls of the ground round Pen-y-parc, toward the neighbourhood of which the strike of the Bangor rocks directly leads.

That the slates overlying the purple beds of Bangor are Arenig beds there is no doubt, and these, as may be seen, also strike straight across Bangor flats to the low ground in Anglesey occupied by dark slates, thin grits, and pisolitic iron-ore that lies east of the metamorphic ridge behind Baron Hill, Henllys, and Tan-y-coed. If the whole region were raised a few fathoms, and the space between Bangor and Beaumaris occupied by alluvium, any geologist tracing the boundary between the Arenig slates and the underlying altered rocks, would have little or no hesitation in uniting the two areas by a dotted line, expressive of the concealed position of the junction of the Arenig and Cambrian strata.

If we now look at Merionethshire, Caernarvonshire, and Anglesey as one large area about 60 miles in length, from south to north we get the following result.

In Merionethshire near Dolgelli, Portmadoc, and Ffestiniog, the Tremadoc, Lingula, and Menevian beds are from 6,000 to 6,800 feet thick, and on the ground near Maentwrog the Lingula flags alone are about 4,000 feet thick.

In Caernarvonshire in the Passes of Nant-ffrancon and Llanberis there are no certain Tremadoc slates, and the Lingula grits and slates are only about 2,000 feet in thickness.* In that case they have either thinned out to half the thickness which they attain in Merionethshire, *or the upper part of them has been unconformably overlapped by superincumbent strata in a distance of* 10 *miles.*

At Bettws Garmon following the south-west strike of the beds we find these *superincumbent strata* to consist of the Arenig beds, lying only *from* 1,000 to 1,100 *feet above the Cambrian grits and slates,* with but little space between them for the Lingula beds, for if such be present, the 2,000 feet of these strata on Elidyr Fawr have thinned away or if not have been overlapped in a direct distance of four miles, so that at the most only 200 or 300 hypothetical feet of Lingula beds could lie between the Cambrian and Arenig strata.

In an area still further north-west, that of Caernarvon and Bangor, *there also we find undoubted Arenig beds lying at Bangor directly on Cambrian strata,* and crossing the Straits to Anglesey in the same position. In this case the whole of the Lingula beds of Llanberis and Nant Francon have totally disappeared in a distance of about four miles.

Taking all these details into account I see no reason to resist the opinion, so long felt and expressed by me, that in this region there is an actual unconformity between the Arenig slates and the rocks below. This unconformity, before the last great disturbance of the rocks, need not be of an extreme kind, but at the time when the Arenig beds were being deposited somewhat in the manner shown in the following diagram. Fig. 103.

There from the neighbourhood of Moelwyn near Ffestiniog by Llanberis and Nant Francon to the neighbourhood of Bangor, the angle of the strata underlying the *horizontal* Arenig beds would only require to dip about two or three degrees while the overlying flatlying Arenig strata were being deposited, though it might well have been considerably more without being suspected or detected by the eye in any particular place, after the subsequent disturbance and denudation of the whole of the formations of an area so large as that of North Wales.

To those who are accustomed to geological mapping on a large scale there is nothing startling in these conclusions. Such unconformities are apt to be not mere small local accidents, but on the contrary are often of wider application. Going much further west than Anglesey, into Ireland, Llandeilo strata (possibly Arenig beds) are sometimes inferred, and in one or more

* No Menevian beds have yet been observed in this country. In great part of North Wales they are never more than 100 or 200 feet in thickness, and whether or not they are present in Caernarvonshire does not affect this argument.

Fig. 103.

1. Cambrian grits and slates.
2. Lingula grits and slates.
3. Arenig beds.
4. Llandeilo and Bala beds.

places are *seen* to lie directly and quite unconformably on the upturned and denuded edges of Cambrian rocks. Let any one who doubts this consult the remarks on the Cambrian and Llandeilo strata of the east of Ireland in the explanations of the maps of the Geological Survey, by the late Professor Jukes, Mr. Du Noyer, and by Professor Hull, especially the note by Mr. Jukes at page 42 in the second edition of the Explanation of Sheets 102 and 112. Professor Jukes's opinion was most decided as regards the unconformity of the Llandeilo on the Cambrian strata in county Wicklow, and this is the reason why the Tremadoc and Lingula beds have not been discovered in that part of Ireland. Mr. O'Kelly also states, that without a doubt a decided unconformity is seen on the coast of Wexford at Roncy Point, six miles S.S.E. of Gorey, which he visited with Mr. Kinahan.

In the north-west Highlands of Scotland also unconformities of the most extreme kind, which I saw with Sir Roderick Murchison and partly mapped in 1859, are visible in the mountains of almost every loch from Loch Carron opposite Skye to Loch Erribol near Cape Wrath. In these regions the Arenig beds, or Lower Llandeilo beds of Murchison, rest sometimes on the markedly denuded edges of Red Cambrian conglomerates and sandstones, and sometimes on the Laurentian gneiss on which the Cambrian rocks also lie in a most strikingly unconformable manner.

To those persons who are accustomed to view stratigraphical questions in this broad manner, there is nothing more remarkable in the minor unconformity of the Arenig beds on the subjacent strata in Caernarvonshire and Anglesey, than there is in the great unconformity of Upper Llandovery beds on the Caradoc, Llandeilo, and Cambrian strata of Shropshire, Builth, and Caernarvonshire, about which no reasonable geologist can entertain a doubt.

Beyond the areas in which Arenig beds are found in Anglesey, the Llandeilo and Bala rocks occupy a large space between Tywyn Trewan on the south-west and the coast north of Dulas Bay on the north-east, as already explained. No group of Arenig fossils is yet known in that area, and unless such fossils should be found at the base of these Llandeilo and Bala beds, it may have happened that the Llandeilo strata entirely overlapped the lower edge of the Arenig beds in part of the area now known as the middle of Anglesey.

CHAPTER XXVIII.

ANGLESEY CONTINUED. THE OLD RED SANDSTONE, CARBONIFEROUS, AND PERMIAN STRATA.

Old Red Sandstone.

Though the chief object of this book is to describe the Lower Silurian and Cambrian rocks, it will be well, before closing the subject of Anglesey, briefly to notice the newer formations of the island in ascending order.

On the east coast the Upper Old Red Sandstone commences in Dulas Bay. A fragment of it is exposed at low tide on the beach opposite Llanwenllwyfo, resting unconformably on the red metamorphic micaceous and talcose rocks from the waste of which it was made, and which, as far as their colour is concerned, may probably have been stained red by solutions bearing iron derived from the unconformable red sandstones that overlie them, long before the outline of the country received its present conformation. Further south the main mass appears lying, also unconformably, on Silurian shales, generally in the manner shown in the 6-inch Section, No. 3 of Sheet 40. It is there about a mile in breadth, and forming a bold escarpment above Traeth Dulas, it dips and undulates easterly at angles of 10°, apparently partly faulted against, but generally dipping under, the basement beds of the Carboniferous limestone. From the coast it trends southerly in a sinuous strip, lying indifferently on Silurian and Cambrian rocks, to the neighbourhood of Llangefni, where it is cut off by a small fault, and overlapped by the limestone, for beyond that point it does not reappear between the Carboniferous limestone and the Cambrian rocks south-west of Llangefni. Where seen its base consists of a coarse conglomerate of quartz, quartz-rock, gneissic rocks, &c., derived from the waste of the older strata. In some cases these pebbles are embedded in a base made chiefly of the red micaceous matter of the adjacent metamorphic Lower Silurian rocks, like that in the detached patch on the shore opposite Llanwenllwyfo. The remainder consists of red and grey sandstone and cornstone (impure concretionary limestone), with thin partings of red marl, and the entire formation is about 600 feet thick. No fossils have yet been discovered in any of its beds, but, should they be found, they will probably be plants akin to those in the uppermost Old Red Sandstone of Ireland, which some persons now incline to place with the Carboniferous series. I have no doubt that this particular part of the Old Red Sandstone was deposited in an inland lake in the manner inferred long ago by Mr. Godwin Austen and insisted on by me in a memoir published in the Journal of the Geological Society in 1871, and if this be the case then the whole of the Old Red Sandstone, as distinguished from the Marine Devonian beds, form in its

continental characters a fitting introduction to much of the overlying Carboniferous strata.

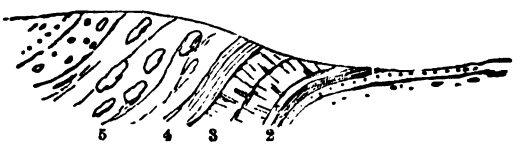
Carboniferous Limestone.

The Old Red Sandstone is overlaid on the east by the Carboniferous limestone. On the shore of Lligwy Bay, within a short distance of the section, the base of the latter formation is so much broken and shattered that there is reason to believe that at this point the two formations are brought against each other by a fault which dies away further south. The base of the series here consists of about 200 feet of irregularly bedded sandstone and conglomerate, formed of pebbles of quartz, quartz-rock, sandstone, &c., rounded and sub-angular, and ranging in size from a grain of sand to 2 feet in diameter, all seemingly derived from adjacent older rocks. Associated with these are what may be called nests of hard grey limestone, sometimes a yard in diameter, and larger lenticular irregular beds of the same rock full of large productas, encrinites, and corals. Near the top there is a bed resembling cornstone, and the whole of these sandy beds range south in a narrow band with the Old Red Sandstone for 8 miles, from Lligwy Bay to the neighbourhood of Llangefni, where both are cut off by the same doubtful north and south fault that passes through the east end of the town. After that they thin out, or are overlapped, for they do not again appear beneath the limestone that borders the coal-field north-west of Malldraeth Marsh.

These sandstones and conglomerates are overlaid by more ordinary beds of the Carboniferous limestone, differing, however, from the greater deposits of South Wales and Somersetshire in this, that they include beds of sandstone and bands of shale, which, near the base, contain impressions of Annelide tracks; and associated with and above these, there are thin beds of black limestone. The coast section from end to end is finely exposed in the cliffs, and the succession of strata is in general regular and but little broken by faults; but near the base on the coast, a little above the black limestone and shale, the stratification is much broken.

Fig. 104.

SECTION AT THE BASE OF THE CARBONIFEROUS LIMESTONE, LLIGWY BAY.



1. Sandstone and quartz conglomerate, with nests and lenticular patches of fossiliferous limestone.
2. Black shale and limestone, with plants.
3. Grey limestone, about 20 feet.
4. Thin rubbly limestone, about 12 feet.
5. Limestone in great broken brecciated blocks, with quartz pebbles, corals, &c., overlaid by limestone and sandstone.

On the east coast the limestone occupies a tract of about 6 miles in length, between Lligwy Bay and Pentraeth, and from 2 to 4 miles broad between the Old Red Sandstone and the sea. With the exception of the junction beds mentioned above, I have elsewhere described it as "fossiliferous limestone, chiefly grey, with "occasional black and reddish beds, and thin bands of sandstone "and conglomerate near the middle, containing pebbles of quartz, "quartz-rock, black slate, jasper, and other metamorphic rocks, "and impressions of plants." These conglomerates were quarried for millstones. As a whole, from north to south and west to east the strata undulate at low angles towards Pentraeth, where they are more disturbed. A fault passes across the middle of the strata from Penllech on the shore to the Old Red Sandstone, being a downthrow on the north of about 350 feet, by which the millstone bed is repeated, as shown on the 6-inch section, line 6. At Pentraeth, on either bank of the stream, the high dip of the beds indicates an anticlinal curve, and the rocks finally dip against the metamorphic foliated schists at a high angle, clearly indicating a fault. All the beds are, in general terms, fossiliferous, containing *productas*, *spirifers*, *encrinites*, *corals*, &c., common everywhere to the Carboniferous limestone. In this part of Anglesey the topmost beds are not reached, for till we get to Malldraeth Marsh there is no indication of an overlying millstone grit. The total thickness where crossed by the section is about 1,100 feet, and occasionally on the flat-topped hills formed by the highest continuous beds, upright natural pillars of limestone remain, attesting the former presence of higher beds, of which these are the relics (fig. 105). The same rocks are often almost bare of soil, seamed by numerous gaping joints, so widened by the carbonic acid in the rains, that the pedestrian must give good heed to his feet in

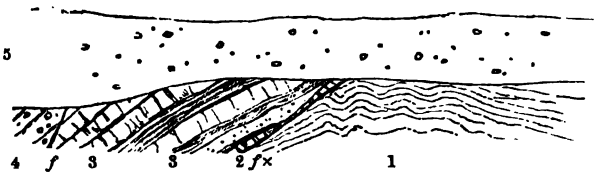
Fig. 105.

traversing the terraces and bare table-land. The pillars themselves are, I believe, the result of the same process of the dissolving of lime by the agency of carbonated rain water, and the topmost beds being absent no man can tell how much has disappeared.

In direct continuation of the limestone south-west of Llangefni the formation forms a long narrow strip on the north-west side of the millstone grit, which it underlies. Here also the beds are occasionally black near the base, but chiefly grey, and they include beds of sandstone. The sandstones and conglomerates that form the base of the series are, however, absent, and there is reason to believe that, passing south-west, the beds are gradually

overlapped in succession, the higher strata by degrees intruding on the foliated rocks below. Where crossed by the 6-inch section (No. 1, Sheet 40, line 3) the limestone is only 450 thick. In the railway cutting many years ago it presented the following section:—

Fig. 106.



1. Green laminated schist, Cambrian.
2. Black limestone.
3. Calcareous shale and limestone.
4. Conglomerate of Millstone grit.
5. Boulder drift.

f. A fault, and *f* × a doubtful fault, but probably an unconformity.

A little further south it thins away altogether, and the millstone grit lies on the altered rocks of Bodorgan. To the Coal-measures I shall by and by return.

The east point of Anglesey is formed of another tract of Carboniferous Limestone, uniting by the intermediate steps of Puffin Island and the Great Ormes Head the larger area west of Red Wharf Bay with the great limestone ranges of Flintshire and Denbighshire. Its south boundary is much obscured by limestone gravel, but its general structure, (the black limestone and shale at its base, and the beds of sandstone and conglomerate it contains near the east point), shows it to represent pretty fully the strata west of Red Wharf Bay. At Penmon it is partly a brown crystalline dolomite, and a little further east it is pierced by a short felspathic dyke. It was from the beds of Penmon that the castles of Caernarvon and Beaumaris were partly built, and from the same quarries, and at Benllech, north of Red Wharf Bay, the great blocks of stone were taken for the construction of the Menai and Britannia Bridges.

The following fossils collected by Mr. Etheridge and myself were found in this district, and named by Mr. Etheridge:—

CARBONIFEROUS LIMESTONE FOSSILS from PENMON, ANGLESEY.

RHIZOPODA.	*Fusulina.*
ACTINOZOA.	*Lithostrotion irregulare.*
	L. junceum.
	L. Martini.
	Cyathophyllum regium.
	Cystiphyllum, sp.
	Amplexus coralloides.
	Zaphrentis cylindrica.
	Syringopora ramulosa.
POLYZOA.	*Fenestella membranacea.*

BRACHIOPODA. *Productus giganteus.*
P. cora.
P. lenticulata.
P. scabricula.
P., sp.
Athyris planisulcata and royeri.
Chonetes papilionacea.
C., sp.
Spirifera glabra.
S. striata.
Euomphalus catillus.
E. pentangulatus.
Loxonema, sp.
Nautilus carinatus.
Bellerophon hiulcus.
Poteriocrinus.
Actinocrinus.
Platycrinus.

PUFFIN ISLAND.

Productus giganteus.
P. cora.
Spirifera striata.
S. glabra.
Athyris.
Fenestella.
Glauconome.
Lithostration irregulare.
L. junceum.
L. floriforme.
Syringopora ramulosa.

Most of the above were collected in the dull, brown, earthy, and cherty limestones and interstratified shales, above the grits S.W. of the Life-boat House at Penmon (on either side of a Small fault). Immediately south of the house the beds are also extremely fossiliferous both in the shales and limestones. The predominating species throughout are—

Productus giganteus -
Lithostrotion irregulare } all abundant.
L. junceum - -

Chonetes papillionacea, in the true hard limestones at Penmon is also abundant in the shale; this shale is usually found in the lower beds throughout England.

Spiriferæ are not at all abundant; indeed rare.

Limestone Series of Menai Straits.—A third broad band of Carboniferous limestone lies on both shores of the Menai, between Bangor and the coast of Anglesey, opposite Caernarvon, forming one area, through which the waters of the straits flow. On the Caernarvonshire side the Carboniferous beds are thrown against Cambrian rocks and that crystalline compound of quartz and felspar of which Twt Hill in Caernarvon forms a part, by one of those great north-east faults which affect the Palæozoic and sometimes the Mesozoic rocks from Shropshire to Anglesey, and which are so closely related to their average strikes. Here, south-west of Bangor, the strata consist of gritty white and sometimes red sandstones, conglomerates, and shales containing Carboniferous plants, and bands of limestone with productas, corals, &c., the various kinds of beds wedging in and out among each other so irregularly that even on a large scale of map it would probably be very difficult to separate them. With various undulations, as a whole they dip south-east, at angles from 10° to 15°, except near the fault, where this dip is often suddenly reversed

At the base of the cliff, for some distance on either side of the Menai Bridge, there are beds of red shale or marl, different in character from the Old Red Sandstone, and intermingled with sandstone and quartz conglomerates of a Carboniferous character. These cross the straits and pass under the limestone of Plas Newydd, both dipping about 15° southerly, and at the base of the red shale lie beds of grit and conglomerate.

On the Anglesey side of the straits the Carboniferous rocks are about 1¾ miles broad, ranging from Llanfair-pwllgwyngyll near Menai Bridge to Traeth Melynog, opposite Caernarvon. They lie upon the gneissic rocks highly unconformably, dipping south-east at angles of about 4° or 5°. The base is generally very obscure, being covered by drift clay with boulders; but lying on low ground under a marked escarpment, it is considered probable that it consists of shales, bands of limestone, marls, and sandstones, generally (though varying) like those of Plas Llanfair and the Menai Bridge, and of the lower beds of the limestone series in Lligwy Bay and on the coast towards Puffin Island. The main mass between the escarpment and the straits consists chiefly of grey and occasionally of reddish and black limestone, with the usual fossils, and occasional bands of sandstone and calcareous conglomerate; and on the south, opposite Caernarvon, these are overlaid by red marly shales, dipping south-east at low angles, so bright in colour that in an old edition of Greenough's map I have seen them coloured as New Red Marl. The same strata occur on the opposite shore, where they consist of soft red and green marl, with layers of sandstone, dipping south-east about 5° against the granitic rocks of Caernarvon. They may be seen on the shore and in brick pits at Y-rhadd-dir, where it is said they bored 60 yards through red marl and layers of sandstone in search of coal. The same red beds are underlaid at Llanfair-is-gaer by a coarse conglomerate composed of pebbles of Carboniferous limestone and chert, Cambrian grit, quartz porphyry like that of the neighbouring masses, black slate or shale (rare), older conglomerates rounded into pebbles, greenstone, various other felspar porphyries of Caernarvonshire, and a red one in great quantities, the native place of which is unknown. The whole has a shingly beach-like aspect, and doubtless was once the beach of the old Carboniferous waters that washed a land formed of highly disturbed Cambrian and Silurian rocks, of which the crystalline boss against which the conglomerate is faulted formed a part. As already stated, five small greenstone dykes penetrate and slightly alter the rock. It is succeeded by beds of red conglomerate, sandstone, grit, and dolomite at Dinas on the shore, beyond which are the more ordinary beds of the Limestone series. A small outlier of Carboniferous limestone lies on the hill by Coed Helen across the river from Caernarvon, but its precise stratigraphical position is unknown. When the country was mapped, it was considered by Mr. Selwyn and myself that these overlying red marly beds and the coarse conglomerate of Llanfair-is-gaer belonged, like the lower red marly strata near Menai Bridge, to the Carbo-

niferous series. Lying also above the highest known limestone beds of the straits, it was thought that it formed part of the lower Coal-measures, but on the other hand it is possible, though very improbable, that they may belong, with the red marles on the opposite shore, to some portion of the concealed Permian strata (fig. 107) which, hidden by peat and superficial detritus, I discovered lying unconformably above the Coal-measures of Malldraeth Marsh, some years after the publication of a first series of the maps. The thin beds of coal in these strata near Caernarvon seem clearly to point to their Carboniferous age.

Coal Measures.

Between 3 and 4 miles from the straits, and resting on the Carboniferous limestone, lies the little coal-field of Malldraeth Marsh. Together they lie in a hollow of the older rocks, and by help of a fault that bounds it on the south-east, the coal-field has been preserved from complete denudation. This fault is shown in the section, fig. 107, and is a downthrow on the north-west of about 2,300 feet.* Together with the Permian beds these Coal-measures form the entire sub-strata underneath Malldraeth Marsh. The length of the coal-field is 9 miles from the neighbourhood of Hirdrefaig to Malldraeth Bay, where it passes out to sea under the sands, which are covered at high water. Its breadth is about 1½ miles. The whole forms a marshy tract, which, excepting the edge of Millstone grit, is almost entirely below the high tide level, for the river is banked nearly to the north-east end of the coal-field, to prevent the daily overflow of the tide. The river itself, together with some minor sluggish streams and stagnant pools, soaks down into the Carboniferous and Permian beds, which generally dip south-east towards the boundary fault, and so saturates the porous strata with water, that its drainage into the coal-pits forms a serious difficulty in working.

The utter absence of surface sections, the small number of coal pits, and the imperfect nature of the records that in old times were kept of most of the shafts and borings, rendered it impossible in 1848 to make out accurately the details of the structure of this coal-field, small as it is. The part best known there is in the neighbourhood of the Holyhead road, at the Penrhyn and Berw pits. Here and in the neighbourhood as far as is known, it seems likely that the thickest coal-measure strata and the greatest number of beds of coal occur, the result, probably, of concealed faults throwing in certain beds not found elsewhere in the south-western part of the area.

The following section shows the general arrangement of the strata in and surrounding the Berw coal-pits:—

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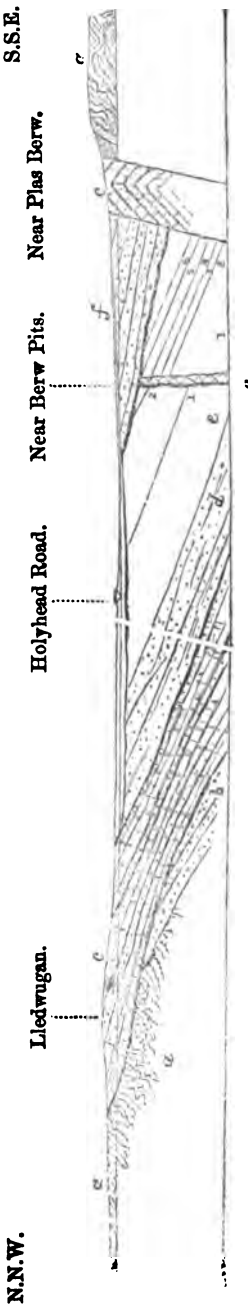
* See p. 266.

Fig. 107.

SECTION ACROSS THE COAL-FIELD OF ANGLESEY.



Scale, three inches to a mile.

a. Silurian, and Cambrian rocks.
b. Old Red Sandstone.
c. Carboniferous Limestone.
d. Millstone Grit.
e. Coal-measures.
f. Permian strata.
g. Greenstone dyke and fault.

On the north-west of the section at the base lie foliated Cambrian schists, and between them and the Carboniferous limestone the hypothetical position of a few beds of Old Red Sandstone and basement Carboniferous conglomerate are indicated, for, a little further north-east, these are overlapped by the limestone, and if their strike be continued underneath the surface they would lie somewhat as shown in the section. Above them lie the ordinary beds of the Carboniferous limestone, and these are succeeded by the Millstone grit and Coal-measures dipping south-east about 20° to 30°, this inclination being known by the beds of Millstone grit on the edge of the coal-field, and for the Coal-measures, which are everywhere concealed under the marsh, by the known dip of the strata in the neighbouring coal-pits. The Millstone grit is about 400 feet thick. It consists of yellow sandstone and conglomerate, and contains a bed of coal from three-quarters to one yard thick, heretofore worked at Glantraeth, and which I have therefore called the Glantraeth coal. Above the grit there are seven other beds of coal, distinguished by the miners in the ordinary Coal-measures, and I am not aware that any more are known in the coal-field. The following appears to be the order of the entire Permian and Carboniferous series of Anglesey, made out as low as the three-quarter coal from the Berw coal-pits, and below that, gathered from imperfect data in the surrounding country. The section between the three-quarter coal and the Millstone grit is therefore doubtful, and there is also considerable doubt both as to the position of the Glantraeth coal in the grit and the thickness of sandstone above it. The precise details also of minor variations of the strata in the shafts have not always been preserved, various beds having been apparently sometimes massed by the miners.

SECTION OF THE BERW PITS AND PROBABLE POSITIONS OF THE UNDERLYING STRATA.

		ft.	in.	ft.	in.
Superficial detritus.	Clay and sand	24	0		
	Turf	3	0		
	Gravel	2	0		
				29	0
Permian.	Red sandstone, conglomerate and marl			195	0
Coal-measures.	COAL ("Glo pux") "lying in lumps;" unworkable	9	0		
	Shale	51	0		
	COAL	3	0		
	Shale	63	0		
	COAL	4	0		
	Soft shale	24	0		
	Hard white rock (Sandstone)	12	0		
	Hard shale	12	0		
	Hard red rocks (Sandstone)	27	0		
	COAL, irregular ("Glo pux")	2	0		
	Hard shale	36	0		
	Soft shale	7	0		
	COAL	6	0		
	Soft shale	12	0		

	ft.	in.	ft.	in.
White sandstone slightly tinged with red	60	0		
Black shale	18	0		
Coal, with 6 inches Cannel on top (¾ Coal)	1	8		
Sandstone and shale, probably about	300	0		
Coal (probable position of Berw-uchaf Coal, in three beds with thin partings)	7 to 8	0		
Shale and Sandstone, probably	650	0		
Coal, probable position of the Glantraeth Coal in Millstone grit	2 to 3	0		
Millstone grit, bottom division	200	0		
			1,508	8
Carboniferous limestone at Llangristiolus			450	0
			2,182	8

It is probable that about 200 feet of sandstone above the Glantraeth coal belongs to the Millstone grit.

Where crossed by this section, none of the above coals crop to the surface under the marsh, except the Glantraeth and probably the Berw-uchaf coals. The remainder, from the 6-feet coal upwards, belong to a higher part of the series, thrown in by faults *which occurred before the deposition of the Permian strata*, against the base of which the coal beds crop. A greenstone dyke, shown in the section, rises in one of these faults, but does not penetrate the overlying Permian strata.

In the north-east angle of the coal-field, west of Llanfihangel Esgeifiog, only a low part of the Coal-measures is believed by me to exist, including, probably, the Glantraeth coal, and possibly a little of the 6-feet coal and the coal of Berw-uchaf; but the information was too imperfect to make this certain, though the most northerly of the east and west faults is said only to be a downthrow on the south of 7 yards. If this be so, and the ground remain untroubled, the 6-feet coal may underlie the Permian rocks north of the fault for a little space, and the Berw-uchaf coal, if constant, may rise in the marsh. Three east and west faults, all downthrows on the south, cross the Holyhead road (*see* Map 78 S.W.), and are said to be cut off by a north and south fault which passes from the great north-east boundary fault near Plas Berw towards the 16th milestone, and being a downthrow on the east may perhaps be a continuation of the fault that passes through Llangefni, throwing the Carboniferous limestone against the foliated rocks on the west; but the evidence of both is lost in the marsh. Between the east and west faults at the Penrhyn pits, the north and south and greenstone or rock-faults, and the great boundary fault, there is a triangular space crossed by the section in which the upper coals of this area lie beneath a thick covering of Permian strata. Between the two northerly faults, which are only about 55 yards apart, the 4-feet coal is said to have cropped against the Permian beds near the surface, and

either there or between the middle fault and that to the south the 6-feet coal was said to be worked at a depth of 60 yards. The strata are said here to lie flatter than they do further south at the Berw pits. The southern of the east and west faults is said to be a downthrow on the south of 69 yards, but this is doubtful as far as I know; and the greenstone or stone fault is a downthrow of 154 yards on the east, where it curves round to the south, as marked on the map, and of 69 yards where it strikes east and west by the pits in the lines which represent its course beneath the Permian strata. In the Berw pits within this space shafts have been sunk and the coals worked, dipping south-east in the manner shown in the section. Only the ¾ coal rises west of the stone fault, where it is believed to abut on the bottom of the Permian strata, and though unproved, it seems probable that the Berw-uchaf coal, uncovered by Permian strata, may crop somewhere under the marsh. This is, however, very uncertain north of the rock fault, as it may be that the ¾ coal is entirely cut out by these faults, throwing the upper measures in the north part of the field exclusively against the strata that lie between the Berw-uchaf coal and the Carboniferous limestone.

It is reported that a north-west fault runs from the boundary fault west of Berw-uchaf towards the greenstone fault in the direction of Llangristiolus, being a downthrow on the north-east, and throwing in some of the higher strata, but its amount I was unable to ascertain. It seems to me, however, that there must be a fault nearly in the position indicated on the map, for west and south of it only the Berw-uchaf coal and the lower minor beds are known, and, indeed all that is known of this part of the coal-field would seem to indicate that the smaller faults west of the boundary fault having occurred before the Permian epoch, the upper coals in this part of the coal-field were denuded away before the deposition of the Permian strata. The sinkings at Berw-uchaf confirm this. In these the 8-feet coal was passed through at a depth of under 60 yards, a little north-east of the pool marked in the map. The section was as follows:—

"Alluvium" -	- 12 yards.
Red Sandstone (Permian)	20–25 „
Coal-measures -	- 20 „
Coal in three parts -	- 8 feet, about 2 feet good.

Here below the Permian rocks (against which it is supposed the 8-feet coal crops) there are only 60 feet of strata above the 8-feet coal. Judging roughly, from the position of the probable outcrop of this coal with regard to the Millstone grit and the Glantraeth coal, it is considered probable that, as the beds lie flatter than at the Berw pits, there is not space sufficient for the three-quarters and higher coals to come in between the Berw-uchaf pit and the boundary fault. It has yet, however, to be proved that this is the case. Further south the Glantraeth coal, about a yard in thickness, has been worked in the neighbourhood of the railway.

Permian Rocks.

Though the Permian rocks are nowhere seen on the surface, their existence in this district may nervetheless be considered certain. The red rock that covers the eastern half of the Coal-measures is perfectly known to the miners. It was sunk through north of the Holyhead road in the coal pits there. Its thickness at the Brew pits is ascertained to be 195 feet, dipping south-east like the Coal-measures, but at a lower unconformable angle. Red rocks of the same kind were also passed through in a trial boring west of the greenstone fault. At the Berw-uchaf pit it is about 25 yards thick. About 1½ miles further south, near the road that crosses the road from Llangaffo, a trial was made and red sandstone found, but in the western half of the coal-field about the Glantraeth pits, both old and comparatively new, shafts and borings after passing the alluvium, &c., sank at once into Coal-measure shales. When I saw the red rocks that had been brought up from the upper part of the shafts, I at once recognised lithologically their Permian character in the red sandstones and occasional angular conglomerates with blotches and partings of red marl. The inference was further confirmed by information that some of the beds of coal crop up against the base of these red rocks, and that the minor faults, including that filled with a greenstone dyke, do not penetrate the unfaulted red sandstone. It thus evidently lies unbroken and unconformably upon the faulted and denuded surface of the Coal-measures and greenstone below; and therefore there seemed no doubt that the unconformable strata must be Permian, especially since they are quite unlike any part of the New Red Sandstone, while similar rocks overlie the North Wales coal-field south of Wrexham. The existence of this outlying patch of Permian rocks in a situation so unexpected is interesting, especially as it is certain that neither it nor the coal-field would exist in Anglesey, but for the north-east boundary fault.

The Boundary Fault.—Between Berw-uchaf and the sea the great fault, being a downthrow on the north-west, causes the Permian and Coal-measure strata to abut on Cambrian rocks; but north-east of Berw-uchaf the amount of the general throw decreases, and between the two faults a strip of Carboniferous limestone comes in, abutting on Permian and Silurian rocks in the manner shown in the section, fig. 107. There can be no doubt that the limestone underlies the coal-field, for the small outlier at Plas Llangaffo east of the fault proves this, and the amount of the throw of the great boundary fault may be thus approximately obtained. Where crossed by the section near Plas Berw, the western fault is a downthrow on the north-west of 2,300 feet. The eastern branch, throwing the limestone against the Silurian rocks, is a downthrow in the same direction of uncertain amount, but probably not exceeding 400 or 500 feet, estimating the thickness of this limestone to be approximately the same with that on the opposite side of the coal-field.

With regard to the coal-field, I repeat, that but for the great boundary fault throwing down the rocks so deep, neither Coal-measures nor Permian rocks would have been saved from the average plaining effects of old denudations, probably in great part marine. Had the Coal-measures not been preserved by this fault, their existence at any period in the Anglesea area would perhaps never have been dreamed of by the generality of observers, for the area that, in consequence of the fault and the denudation of the soft Permian rocks and Coal-measures, is now the valley of Malldraeth Marsh, might without the fault have shown only a broad continuation of the limestone that lies between Pentraeth and Lligwy Bay; the overlying strata of Coal-measures, that once overspread the limestone, having in such a case and in that area been removed by denudation. As the limestone may be safely inferred to underlie the coal-field, there can be no doubt that it once extended further to the south-east, the little outliers of sandstone of the limestone series at Plas Llangaffo and Ty'n-twr indicating that it once extended across the schists and joined the limestones of the straits. The bold western escarpment of the limestone south of Lligwy Bay, clearly shows that it once spread far westward across the Silurian and Cambrian strata, and the same argument may be applied to the fine escarpment of limestone that overlooks the Arenig beds between the remarkable old camp of Bwrdd Arthur (Arthur's Table) and Penmon opposite the Lavan sands. No one can doubt, therefore, that the Carboniferous rocks once overspread the whole of the south-eastern part of the island, and I have no doubt the same was the case with its north-western half. It is in fact easy to infer that the whole of Anglesey and at least all the low ground of Caernarvonshire, and perhaps even a great part of Lleyn, were once covered by Carboniferous strata. Such great denudations are not the exception but the rule.

It may have been that this region was also once covered by formations much younger than the Permian strata, but with such inferences this volume has nothing to do. Whatever incidents of that kind occurred, one of the last of any importance, and but a minor one, was the separation of Anglesey from the mainland in the manner described in Chapter 29.

If we briefly pass in review the chief features of the geology of Anglesey, the sum and substance is as follows, and it has a distinct meaning when taken in connexion with that of the neighbouring county of Caernarvon, and the more distant region of Merionethshire.

1st. The Cambrian rocks of Anglesey were disturbed and somewhat metamorphosed before the deposition of the Arenig sla[illegible]ame which lie unconformably upon them, and which are overlai[illegible]hich Llandeilo and Caradoc beds, which possibly in places may di[illegible]ide o[illegible] overlie the Cambrian strata, though this is unproved. [illegible]les.

2nd. Part of these Silurian rocks, chiefly in what is n[illegible] is to central part of the island, were themselves metamorphose[illegible]h err[illegible] someti[illegible]

nexion with the occurrence of a broad tract of imperfect granite which crosses Anglesey from north-east to south-west, and which, from the difficulty of separating it from the adjoining metamorphic rocks, has always seemed to me to be in itself simply the result of extreme metamorphism.

3rd. On these rocks the Old Red Sandstone lies quite unconformably, having in the absence of Upper Silurian strata no passage or direct connexion with the Silurian strata below, and it is succeeded by the Carboniferous limestone, Millstone grit, and Coal-measures. All of these are intimately connected with each other, forming a regular ascending series of sub-formations, and only overlapping each other in the slight way that, for example, elsewhere we find an upper member of the Coal-measures overlapping lower strata of the same series.

4th. If we consider the meaning of the bold escarpment of the Old Red Sandstone at Traeth Dulas, it is clear that it has been formed by denudation, and, therefore, that at all events a considerable part of the underlying rocks of the country were once covered with Old Red Sandstone; and,

5th. It seems to me, after long and minute acquaintance with Wales, that what is now Anglesey and the neighbouring low-lying parts of Caernarvonshire (and much more besides, now partly wasted by denudation, and partly covered by the sea) was a low undulating country, which by degrees got deeply buried under Old Red Sandstone and Carboniferous strata, so that the whole of what is now the island and wide regions beyond were altogether concealed by these overlying formations.

6th. At a later date the Coal-measures and underlying strata were so far upheaved, that the Coal-measures suffered great waste and denudation, and the Permian strata were deposited unconformably upon them as part of a wide spreading salt lake,* and these also, as is shown by their dip, covered an extensive region, quite beyond their present restricted range in Anglesey.

* *See* "The Red Rocks of England of older date than the Trias," Ramsay, Journal of the Geological Society, Vol. 27, 1871.

CHAPTER XXIX.

ANGLESEY—CONTINUED. HOW IT BECAME AN ISLAND.

HAVING explained the Geology of Anglesey, and its relations to that of the mainland, I will now endeavour to show how it became an island, and in connexion with this subject I will give a brief sketch of some of the leading points of the glaciation of North Wales, without which the description of the geology of the mountain region would be incomplete. It must however be understood that I by no means intend to enter into all the details of that wide subject, having long ago partially done so in a memoir on the Old Glaciers of North Wales.

The structure of the low ground of Caernarvonshire within three or four miles of the Menai Straits in almost all respects resembles that of Anglesey, both in its geology and physical geography. The Menai Straits divide the two regions; but Carboniferous rocks form the larger part of either shore, and the Straits may be considered simply as a long shallow valley, the bottom of which happens to lie beneath the level of the sea. The question thus arises, At what epoch and by what means was Anglesey separated from the mainland?

Looking north-west across the country from any of the minor heights a mile or two inland between Bangor and Caernarvon, no one would even suspect the existence of the Straits. The whole of the island is low; and only one steep escarpment, a minor one, occurs—that of the Old Red Sandstone overlooking Traeth Dulas, which rises abruptly above the tidal flat of the Traeth to the height of about 250 feet.

The entire island may, indeed, be looked on as a gently undulating plain, the higher parts of which attain an average elevation of from 200 to 300 feet above the level of the sea, while most of its principal brooks and small rivers run north-east and south-west, in depressions with gently sloping sides; and only one inland valley, with the same trend, is of any marked importance, namely that of Malldraeth Marsh, in which the small coal-field lies. There are, however, a few exceptions to the average levels mentioned above—the summit of Holyhead mountain being 709 feet, and Garn, near Llanfairynghornwy, 558 feet above the sea, while the greatest elevation crossed by the sections of the Geological Survey (Section 6-in. to a mile sheet No. 40) is only about 400 feet high.

On the opposite side of the Straits the same kind of low undulating scenery prevails for several miles inland, with the same kind of minor north-east valleys, one marked instance of which occurs in a long shallow and narrow valley in or alongside of which the Caernarvon and Bangor road runs for several miles.

The surface of the ground on both sides of the Straits is to a considerable extent composed of glacial detritus, with erratic boulders, large and small (from the north), gravel, sometimes

sand, and clay from which any number of ice-scratched stones may be gathered from well-exposed sections, as, for example, in the boulder-clay coast-cliff of the Mount at Beaumaris (which contains very rarely minute fragments of sea-shells), or anywhere else in similar cliffs round the shores of Anglesey, or inland in occasional pits and fresh cuttings on both sides of the Straits. Through these glacial accumulations the rocks of the country frequently appear, sometimes in barren tracks of considerable extent, sometimes in small isolated bosses of gneiss or grit, often covered with heath or furze, while the more fertile grounds of the whole of Anglesey consist chiefly of glacial detritus, with here and there small alluvial meadows by the sides of the streams.

When freshly stripped of glacial *débris*, or even of a mere thin turfy soil, the underlying rocks are often found to be ice-smoothed and marked with glacial striæ, *running generally from about* 30° *to* 40° *west of south*. The larger valleys of Malldraeth Marsh and the Menai Straits (with others of minor note) run in hollows in the same general direction.

It is well known that in all mountain regions where glaciers exist, or have in past times existed, the disturbances of the earth's crust that produced the elevation of the mountains go back to periods long antecedent to the last great Glacial epoch. Thus the first great upheaval of the Alps is of præ-Miocene age, and the mountains of Scotland and Cumberland were mountains before Old-Red-Sandstone times, while the last great movement of the rocks of Wales is certainly older than the Permian epoch, and, probably, like the mountains of Cumberland, very much older.

There was therefore plenty of time, in what is now Wales, long before the beginning of the great Glacial episode, for the more ordinary agents of denudation to have formed deep valleys, down which, when that episode began, the growing glaciers might gravitate, deepening their channels as they pressed forward, and mamillating and striating the rocks over which they slid; for the great original valleys of these mountains were by no means entirely scooped out, but merely modified by the glaciers.

Thus, for example, it happens in Wales that all the striations in the valley of Dolgelly and the estuary of the Mawddach, in Merionethshire, follow the south-westerly trend of the valley, the glacier that filled it when at its greatest being fed by the snows of the slopes of Cader Idris and Aran Mowddwy and those of the tributary valleys of Afon Eden and the Mawddach, that joined it from the north, while from a central low watershed near the sources of the Wnion, another branch pressed north-easterly into and beyond the region now occupied by Bala lake.

The striated rocks exposed at low tide among the sands in the estuary of the Mawddach, and the islet-like heathy bosses of rock that stand out amid the marshy moss opposite Barmouth, are merely *roches moutonnées*, once buried deep beneath the glacier that pressed forward into Cardigan Bay.

In like manner all the western valleys of the Cambrian mountains of Merionethshire, from Barmouth to Diphwys west of

Trawsfynydd, such as those of Afon Atro, Ardudwy, and Afon Ysgethin, are marked by deep grooves and striations pointing more or less westward, according to the trend of the valleys.

In ascending the valley from Llanbedr on the coast south of Harlech to Llyn-cwm-bychan, the experienced eye is at once attracted by the long smooth sweeps of the ice-ground rocks of Mynydd Llanbedr all trending towards the west, and from the summit of Graig-ddrwg looking south towards Rhinog-fawr the same effects of old glacier ice are seen on a still grander scale. The deep craggy pass of Bwlch-drws-ardudwy is itself strongly ice-grooved, while the western flanks of Graig-ddrwg are covered with deeply incised striations up to the very summit of the mountain, all trending westward. The rock-bound hollows of Llyn-cwm-bychan and other mountain tarns in like manner tell of the effects of thick masses of glacier-ice.

The broad flats and roughly hilly, but not mountainous, country of Crawcwell, Cors-goch, Afon Eden, Trawsfynydd, and the ground bounded by the amphitheatre of scarped mountains formed by the Arenigs, the Manods, the Moelwyns, and the Cambrian steeps of Diphwys, Graig-ddrwg, Rhinog-fawr and Cefn-cam, were at the same time filled with deep accumulations of snow and ice, from which were discharged a radiating series of glaciers, one pressing southward to swell the ice-stream that filled the valley of what is now the estuary of the Mawddach, another through the Pass of Afon Treweryn between Arenig Mawr and Arenig Bach eastward towards Bala and the valley of the Dee, there to be aided in the work of erosion by the glaciers that descended from either flank of Aran Mowddwy, one effect of which was to scoop out the rock-bound hollow now occupied by Bala Lake. Further west, swelled by all the snows of the Manods and the Moelwyns, a large glacier flowed south-west, into what is now the broad flat of Traeth Bach, there to be joined by another great ice-stream which, partly descending by Cwm Llydaw and Cwm-llan from the high eastern slopes of Snowdon, filled Nant Gwynant, south of which, aided by tributary ice-streams from Moel Hebog and the long valleys of Nant-y-mor and Cwm-Croesor, it finally debouched into the area now occupied by the marshy flat of Traeth Mawr. In all of these the directions of the striations necessarily conform to the trend of the valleys—easterly, southerly, or south-west, as the case may be.

I mention these specialities of striation partly to show that the Welsh group of mountains, as a whole, was not entirely overridden by a great universal ice-sheet proceeding from the far north, as some have ventured to suppose. In the main, in the truly mountain regions, every large valley was filled by its own special glacier—a circumstance long ago stated in a broad way by Buckland, and definitely worked out by me for Caernarvonshire in my essay in the first volume of "Peaks, Passes, and Glaciers," afterwards republished in a little book. In North Wales, when the country was absolutely full of snow and ice, each great valley still maintained its separate ice-flow. In such a case,

however, there were many deviations consequent on under and upper ice-currents, the upper parts of glaciers diverging from the direction of the under-flow, and passing across what are now low watersheds, like that of Llyn Cawlyd, (misspelt Cwlyd) into neighbouring vales, such as that of the Conwy—a circumstance to which special attention has been called by the Reverend W. T. Kingsley, while engaged within the last few years in sounding the lakes of North Wales, with the view of proving them to be, as I affirmed, true rock-bound basins.

Such statements as these are preliminary to, and necessary for the understanding of, the main point of this Chapter which I will now discuss.

On the north-west slopes of the Snowdonian range* (*see* Map) great glaciers poured their ice-streams down the valleys of Llyniau Nant-y-llef to the west, and of the valleys of Llyn Cwellyn, Llanberis, and Nant Francon to the north-west, that of Nant Francon being much increased in size by the tributary glaciers of Cwm-llafar and Afon-gaseg the chief gathering grounds of which were the cliffy *cirques* or Corries that lie on the western flanks of Carnedd Llewelyn and Carnedd Dafydd. These mountains together with Y-Foel-frâs, formed one great nursery of the old glaciers of this part of North Caernarvonshire, sending off ice-streams eastward to Capel Curig and the valley of the Conwy and north-west towards what is now Menai Straits and the Coast of the Lavan Sands near Bangor. These glaciers however, in my opinion, at this period did not enter and overflow the region now occupied by the Menai Straits, but on escaping from the high bounding-walls of the upper parts of their valleys, they partly spread out in the shape of broad fans on the north-western slopes of the minor hills that now overlook the Straits. This is partly proved by the slightly northerly curve of the glacial striations at the mouth of the Pass of Llanberis, and on the area above the steep slopes of the slate-quarries by Llyn Peris and Llyn Padarn.

The south-westerly striations produced by this great northern glacier across the mouths of the large valleys of Nant Francon and Llanberis, would be apt to be obliterated by the subsequent increase in size of the native glaciers of these passes, and I have reason to believe that the broad mound of glacial *débris* of Penrhyn park and on which Penrhyn Castle stands is only the relics of the terminal moraine, of the large glacier that at a comparatively late period of its history flowed down the valley of Nant Francon and the Ogwen, fed by the snows of the Glyders, Foel-goch, Mynydd Perfedd, and Elidyr-fawr on one side, and by those of Carnedd Dafydd, Carnedd Llewelyn, and Foel-frâs on the other.

An intimate acquaintance with the country on both sides of the Menai shows that the glaciers of Snowdonia did not

* I use the word *range* as a convenient term. There is no range of mountains in North Wales. Taken collectively they form a great group.

cross the Straits into what is now the island of Anglesey; and it is therefore clear that the north-east and south-west striations which mark the whole of that island must have been produced by some other power.

These striations point directly toward the mountains of Cumberland, a country which, lying further north, was at one time buried so deeply under snow and ice that almost all its mountains look simply like gigantic *roches moutonnées;* for Cumberland was even more intensely glaciated than the more southern region of Wales. From Cumberland a vast mass of ice flowed southward; and, reinforced by the ice-streams that came from the mountains of Carrick and the south of Scotland, and from the basin of the Clyde, it overspread the region of what is now the coasts of the Isle of Man, and that now occupied by the shallow sea of Morecambe, Lancaster, and Liverpool bays, that lie between Cumberland and Anglesey, and are nowhere more than 30 fathoms deep.

On or towards its eastern margin this great glacier buried all the hills and knolls of Great Ormes Head, Little Ormes Head, Diganwy, and Penmaen-bach, which are still on a large scale so strikingly *moutonnée*, and pressing along the slopes of Llanfairfechan, the lower part of Aber valley, the seaward flank of Moel Wnion, and across the lower end of the valley of the Ogwen, it marked its track by those long slightly inclined terraces, somewhat faint, but still clear to the experienced eye when looked for from the shores of Beaumaris. Furthermore, this vast ice-sheet overspread the whole of what is now the island of Anglesey, and miles beyond that area it continued its onward course to some unknown distance, for on the ice-ground rocks above the sea-cliff of Trwyn-y-tâl, a mile north of the seaward flank of Yr-Eifl, or The Rivals, well marked striations are seen pointing towards the Straits 43° north of east. With its extreme southern and western margins we have at present nothing to do beyond this, that it covered the whole of Anglesey, the Menai Straits, and the minor hills that lie between the mountains of Caernarvonshire and the sea.

Under these circumstances, so great was the size and power of this ice-flow that it hindered the glaciers of Y-Foel Frâs, Llanberis, and Nant Francon from encroaching on the territory of Anglesey, and these simply joined the large on-flowing glacier as minor tributary ice-streams. For this reason it happens that the glacial striations of Anglesey, as we might at first expect, *do not point towards the old glacier-valleys of Snowdonia that open on the Straits, but run at right angles to the courses of these comparatively minor glaciers.*

If we now turn to the rocks that form the banks of the Menai Straits, we find that they chiefly consist of nearly flat-lying Carboniferous strata (see Map, and also 78 S.E. and S.W. 1-inch scale, and Pl. 6-inch Sections sheets 28 and 31); and looking at the disposition of these strata from Traeth Melyn, opposite Caernarvon, to Llanfair-pwll-gwyngyll, in Anglesey, and on the opposite

shore from Caernarvon to Bangor, there is reason to believe that from end to end they once filled the whole of the region now occupied by the Straits. The larger part of this region, as it now exists, is of Carboniferous Limestone age; but it by no means consists entirely of solid limestone. On the contrary, numerous bands of shale and friable sandstones and conglomerates are intermingled with the limestones, together with beds of soft red marl. On the coast opposite Caernarvon, the low cliffs are entirely formed of red marl overlying the limestone; and on the Caernarvonshire coast for three miles north of the town, also overlying the limestone, there are soft shales of the Coal-measures, sometimes red or green and marly, and containing thin seams of coal.

In Anglesey, from three to four miles north-west of the Straits, lies the valley of Malldraeth Marsh, the rocks of which also consist of Carboniferous Limestone, Millstone grit, soft Coal-measure shales, with a little sandstone, beds of coal, and Permian strata; and this valley, nine miles in length, runs almost exactly parallel to the valley of the Menai Straits. Many years ago, at its north-eastern end, I saw deep glacial striations on the Millstone Grit, running straight down the shallow valley towards Caernarvon Bay.

Considering that the south-westerly trend of each of these valleys (and of others of minor note) corresponds with the general direction of the glacial striations of Anglesey, and therefore with the onward course of the great glacier that produced them, I have been led to the conclusion that both of these shallow valleys were scooped out in comparatively soft rocks by the grinding power of the vast glacier coming from the north-east, and that when in the course of time the climate ameliorated and the glacier disappeared the sea flowed in where parts of the glacier had been, and Anglesey first became an island, the islets in the narrower and shallower part of the Straits at the Menai and tubular bridges being merely weathered *roches moutonnées*, once overridden by the moving glacier.

Malldraeth Marsh, as its name (the sodden sands) implies, is for the most part deeply buried under watery moss and alluvium; the river that traverses it is artificially banked and tidal for miles from its mouth; and if the alluvium that covers its surface, and the blown sands at its mouth were removed, it would again become, as it was in old times, an arm of the sea, a kind of low-banked fjord (like the Menai Straits), about nine miles in length, but, unlike the Straits, closed at its north-east end. Nowhere in the Straits is the water more than from 6 to 10 fathoms deep at high water; and around the islets near the bridges it varies from 3 to 7 fathoms. An elevation of the country of only 42 feet would in time, by silting up and subsequent accumulation of alluvium, turn the north-eastern and south-western parts of the Straits on either side of the islets into valleys like that of Malldraeth Marsh.

There are some details connected with the great old northern glacier that overspread Anglesey, and with the subsequent partial submergence of North Wales which it may be well to mention.

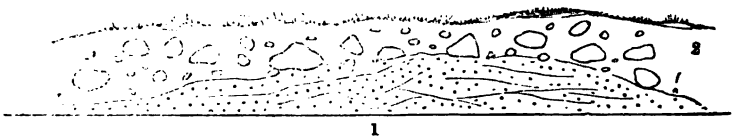
On the sea-coast between Beaumaris and Penmon there are cliffs and banks of boulder clay. The largest of these is The Mount close to Beaumaris. It consists of stiff boulder clay charged with large and small blocks of Carboniferous Limestone, fragments of slaty rocks and Silurian-looking grits, quartz, Carboniferous-looking shale, greenstone, various felspathic traps, granites, and small chalk flints which are by no means scarce and are mostly sub-angular. The greater proportion of the limestone and slaty blocks are covered with glacial scratches. In the upper part of the cliff the material is more loamy, some irregular thin interstratifications of sand appear and the stones are apt to be more weathered.

Low sea cliffs of the same boulder clay occur east of Llanfaes with huge blocks of Carboniferous Limestone (many of which have been blasted and broken up) granite boulders, greenstones or syenites, felspathic traps, small flints, &c., &c., and the whole of the foreshore north-eastward, between Lleiniog and Penmon, is seen at low tide to be strewn with boulders, some of great size, and consisting chiefly of limestone, and partly of quartz conglomerate, both apparently derived from the Carboniferous Limestone region that lies between Lleiniog, Puffin Island, and Red Wharf Bay.

The low cliffs at Lleiniog mostly consist of half consolidated sand and gravel, exceedingly false bedded, and sufficiently hard to form ledges on the shore at low tide. In these gravels there are chalk flints, small pieces of coal and layers of drift, carboniferous shale, ironstone, limestone and quartz-conglomerate, chert, felstone porphyry, red granite, jasper, and possibly pieces of New Red Sandstone.

Above these sandy strata lie boulder beds with limestone boulders, chalk flints, &c., but it is by no means clear that there is a marked line of division between them, for though the upper surface of the sands and gravels is very irregular, it often seems

Fig. 108.



1. Sand and gravel. 2. Boulder-clay.

as if these strata had been, so to speak, *shaken* when the boulder clay began to be deposited, and thus at their junction they got mingled together.

Further to the north-east on the coast under Penmon, the cliff still consists of boulder clay partly overlying sand and gravel similar to that at Lleiniog, and seemingly partly merging into each other,

and whereas towards Beaumaris the erratics are mostly well scratched, as we approach the cliffs of Penmon the loose limestone blocks become much more rough and angular, as if, beneath the glacier ere it retired, they had not been shoved far enough after being rent from the parent rock to acquire smoothed and striated surfaces.

Above the quartzose grit that forms part of the shore at Penmon there is a little boulder clay. The rock beneath is *moutonnée* with faint striations running southerly, and in the clay I found Silurian grit that might easily be that of Cumberland, rounded granite pebbles, flints, &c., and a decaying but well-formed Apporhais.

Above the limestone of the quarries and all along the east and other coasts of Anglesey, glacial deposits are found with stones foreign to the area, such as some of those already mentioned.

If we now examine the coast of Caernarvonshire adjoining the Straits, we find phenomena more or less similar to those described. For example, on the seaward slope of Moel Wnion above Ffridd Fedw, about 800 feet above the sea, there are rounded gravels with foreign pebbles similar to those already noticed, and such gravels are found in places all the way to the sea. Those at and near the railway station at Bangor are looser, but still strongly resemble the gravels of Lleiniog.

Much further south between Caernarvon and Afon Wen and Criccieth, the country is to a great extent covered by loose gravels which probably are older than certain boulder bearing masses, which may rather be inferred than positively seen to lie above them.

East of Llandwrog between Groeslon and Moel Tryfan this is what we find. All the way up hill to Bedd Twrog on Mynydd-y-cilgwyn there is earthy gravel with ice-scratched stones of moraine-like character. On the west flank of the Mynydd there are large banks of rudely stratified moraine matter with numerous scratched stones and boulders of quartz-porphyry, slate, &c., mingled with much sand and well rounded gravel. A few small blocks of quartz conglomerate occur similar to that which is inter-stratified with the Carboniferous Limestone of the Straits or of Anglesey on Penmon. In this gravel Mr. Etheridge found what seemed to be a fragment of a *Balanus*, at a height of about 830 feet above the sea. Looking to the south from the slate quarry on the southern side of Moel Tryfan it is easy to mark symmetrical moraine-mounds on the west side of Mynydd-y-cilgwyn, which form the cultivated land immediately west of the common, while other and similar mounds further west and away towards Groeslon become very apparent.

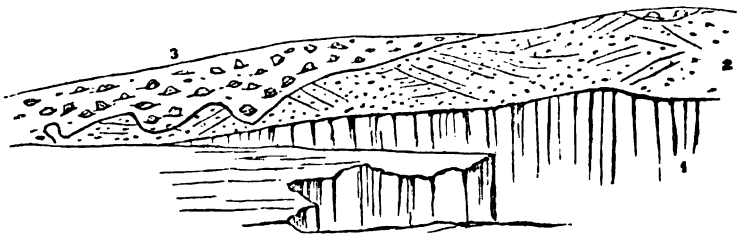
Proceeding towards Moel Tryfan there is an opening close by a deserted quarry with dilapidated offices. This little artificial valley is about 30 feet deep, and a fine spring issues from its upper end, doubtless thrown out by a bed of clay. The section on the side of the valley consists of stratified sand, gravel, and beds of fine clay, in which we found no fossils. Behind the opening there

is a great gravelly moraine-like mound, among the detritus of which there lies a rough angular block of Carboniferous conglomerate about 2 feet in length and breadth. This mound is about 1,100 feet above the sea.

The height of Moel Tryfan is about 1,350 or 1,375 feet above the sea, and the large slate quarry near, and in active work, is about 1,150 feet above the sea level. Above the slaty rock there lie the well known shell-bearing sands and gravels first described by the late Mr. Joshua Trimmer in the year 1831.*

The stratification is exceedingly irregular and marked by false bedding in an extreme degree. Above it, on a much erroded surface lies boulder clay in the manner shown in the following diagram, when we saw the section in 1876, but as excavations are constantly going on the details must constantly vary.

Fig. 109.



1. Cambrian slate.
2. Sand and gravel, with sea shells.
3. Boulder beds.

These gravels are sometimes half consolidated, like those of Lleiniog in Anglesey, and they contain fragments of granite, mica-schist, greenstone, felspar-porphyry, jasper, Silurian slate, chalk flints, &c. The overlying boulder-clay which is unstratified, also contains stones and blocks of felspathic porphyry, greenstone, jasper, quartzite, and slate, some of the fragments being purple. Some of the blocks are very large, and well scratched stones are very numerous in the clay, and in the underlying gravels stones occur with the scratches generally half obliterated as if by the rolling action of waves on a beach. He would be a bold man who could see the ground and still maintain that these well bedded strata have all been shoved up 1,100 feet out of the sea to the ground on which they lie.

The following list of shells from the sands has been made by Mr. Etheridge partly on the spot:—

List of Shells from Moel Tryfan.

Lamellibranchiata.—*Cardium echinatum, C. edule* and var. *rusticum; Astarte borealis, A. compressa*, var. *globosa, A. sulcata; Cyprina Islandica; Tellina Balthica; Saxicava rugosa; Mactra ovalis*; in all 27 species of Lamellibranchiata have been found in these sands.

* Prop. Geol. Soc., Vol. 1., p. 381.

Gasteropoda.—*Trochus magus; Lacuna divaricata, Littorina littorea; Turritella communis; Pleurotoma pyramidalis, P. turricula; Buccinum undatum; Nassa reticulata; Purpura lapillus; Trophon antiquum, T. clathratum, T. scalaroides;* and *Murex erinaceus.* Many other species; in all 28 have occurred.

One important fact being, as I believe, that a great glacier pressing on from the north, glaciated Anglesey, scooped out the hollow of the existing Straits and other minor valleys, and ground its way along the north-western flanks of the Caernarvonshire mountains to a height of not less and probably more than 1,800 to 2,000 feet, and stopped the north-western flow of the glaciers of Wales. If so, what relations have the phenomena described, to the history of the Glacial Epoch in this part of North Wales.

From much personal experience, I am aware that the moraine-matter of glaciers on the greatest scale, is often partly as well rounded as if it had been worn by running water or by the waves on a sea beach. Thus the gravel on and in which the large blocks of Monthey lie in the valley of the Rhone opposite Bex is rounded, and on the slopes of the Jura above Neuchatel the small moraine matter of the same great glacier of the Rhone is also rounded and not devoid of ice-scratches. On the other side of the Alps also, beyond the mouth of the Val d'Aosta, the great terminal moraine of the glacier of the Dora Baltea, 1,600 feet in height and 60 miles in length in its long curved sweep, contains, besides large blocks, quantities of rounded gravel, sand, and clay often well stratified.

It is therefore more than probable, that a great glacier coming from Scotland and Cumberland, should also have made its rounded gravels, the relics of which are now found in Anglesey and on the north-western slopes of the Caernarvonshire hills overlooking the Lavan Sands and Menai Straits. I do not, however, think that from the time of the disappearance of that great glacier to the present day, this moraine-matter has been altogether undisturbed. Many important events followed.

In other writings I have attempted to show that in North Wales (and of course elsewhere) the period of intensest cold, when the mountains and valleys were most buried in snow and ice, was followed by an episode of partial submergence, certainly, as witnessed by the gravels of Moel Tryfan to a depth of nearly 1,400 feet, and in my opinion more probably to a depth of over 2,000 feet, as shown by the shell-bearing drift on the seaward flank of Snowdon near Maen-bras, and the equivalent drifts on either side of Nant-Francon. During the progress of this submergence, the pre-existing moraine matter of the great northern glacier must have undergone extensive remodelling, and the sands and gravels of Lleiniog in Anglesey, of Ffrid Fedw opposite in Caernarvonshire, and of Moel Tryfan and its neighbourhood are among the results. If, as I believe, the cold to a considerable degree continued during this episode of submergence, it may well have been that stones and blocks entangled in coast ice may some-

times have gradually been raised from low to higher levels, in the manner described by Mr. Darwin.

This time of submergence may possibly have occurred during one or more of those episodes now called by the Geikies and some other authors "interglacial epochs." By and by the country was again upheaved to its present approximate level, the glaciers of Wales increased much in size, but never became so large as to intrude all across the area now occupied by the Straits, and it was at this time that the large glacier of Nant Francon deposited the large moraine that now forms the beautiful undulating grounds of Penrhyn Castle. The island was, however, after emergence, apparently partly joined to Caernarvonshire by an undulating plain of Boulder-clay; but by and by, through marine waste and subaerial drainage, this material was so much worn away that only the relics of it now remain in occasional cliffs and low banks on either side of the Straits. Then it was that at length Anglesey fairly became an island such as it now appears, though, the long channel through which the waters of the Straits flow was ground out in the rocks at a comparatively early part of the Glacial epoch.

Such I believe to have been the physical history of Anglesey before, during, and after the Glacial epoch; and thus it was that Anglesey got separated from the mainland of North Wales by what is, after all, merely a long and broad glacial groove.

This with me is no hasty conclusion. Having at intervals been much in Anglesey, and occasionally living on the banks of the Straits for months at a time, I often wondered what might be their meaning. It is difficult, or, perhaps, impossible to look at this long narrow channel, without the idea entering the mind that at some unknown but comparatively recent time, it may have formed part of the course of a large river flowing from some hypothetical land now submerged or destroyed by denudation; and this vague hypothesis possessed me so strongly for years, that, though always in doubt and in search of a better, it helped to blind me to any other. In 1875, however, while looking at the Straits, the whole truth of the case seemed suddenly to flash into my mind. The result I have given in this chapter.

CHAPTER XXX.

Llandovery Rocks, Tarannon Shale and Denbighshire Grits of Caernarvonshire, Denbighshire, and Montgomeryshire.

General Description.—The Lower Silurian rocks are bounded on the east by the Tarannon shale and Denbighshire grit, the last of which is overlaid—from Conway to Llanbadarn-fawr* in Radnorshire—by the Wenlock shale, of which it forms a subordinate part, or rather into which it passes by gradations of lithological character in various directions. From the country round the isolated table-land of Tarannon to Afon Blaen-y-Coed east of the Arans, a band of grit, or grits, underlies the shale, which has been doubtfully referred to the Lower Llandovery beds, simply because of their position, but as no fossils have been found in these grits, they might probably as well be classed with any other high part of the Lower Silurian Series, seeing that the Upper Llandovery rocks are entirely wanting in these areas, and the Tarannon shale lies transgressively on all below.

These rocks, form a border on the east to the Lower Silurian district of Merionethshire and Caernarvonshire, and also surround the Berwyn Hills, and to finish this part of the subject for the present, it will be well to give a sketch of this part of their range.

Between Aran Mowddwy and the Berwyn Hills the section in column is as follows in descending order:—

Wenlock shale and Denbighshire grit } Wenlock beds.
Tarannon shale.
(*Upper Llandovery or Pentamerus beds absent.*)
Lower Llandovery beds?
Caradoc or Bala beds.

Near Conway the members present are—

Wenlock shale and Denbighshire grit } Wenlock beds.
Tarannon shale.
(*Upper and Lower Llandovery beds absent.*)
Caradoc or Bala beds.

Nowhere in this district is there any visible unconformity between the Bala beds and the supposed Lower Llandovery rocks, and the latter are therefore here and near Llandovery included as part of the Lower Silurian series.

Between Conway and the country east of Bala Lake the Lower Llandovery rocks are unknown, partly perhaps, because they have thinned away in their continuation to the north, but the Tarannon

* Between Rhaiadr and New Radnor.

shale and Wenlock strata resting unconformably on the underlying formations, these so-called Llandovery beds may be overlapped. Following the edge of the Tarannon shales southward, they first appear in a very attenuated form about five miles south-east of Llangower near Bala Lake, on the south side of a fault that crosses Cefnbwlan from east to west. They consist of hard beds of grey grit, which thicken by degrees on their southward strike, and soon become intermingled with beds of shale. Throughout all their range of about 20 miles in a direct line to the river Tarannon,* they run in a narrow band, the lower edge of which is rarely more than half a mile from the shale, their thickness rising up to 500 or 600 feet. But east of the great synclinal curve on the Tarannon river the series increases to about 1,500 feet in thickness, and is repeated in a series of rapid contortions across miles of country between Careg-hir and Bryn-Crugog, in the manner shown in the following diagram, fig. 110.

East and south of this they disappear under the Tarannon shale near a house called Dol-friog, perhaps by thinning out, perhaps by overlap. Everywhere in Merionethshire they seem to pass regularly and conformably downwards into the underlying Bala beds, in the manner shown in the diagram (fig. 110), although this conformity is probably either accidental or deceptive, for near Llandovery, in Caermarthenshire, unconformity was detected by Mr. Aveline. Neither can the eye detect, locally, any unconformity between these supposed Lower Llandovery beds and the overlying Tarannon shale, but unconformity may easily be inferred, for the Tarannon shale in many places in Wales and Shropshire lies indifferently on different horizons of the Lower Silurian strata. It is also to be noticed that an important member of the undoubted Upper Silurian series, the Upper Llandovery beds, is altogether absent in this part of North Wales. If present it should lie between the Lower Llandovery beds and the Tarannon shale, as shown in the table at the beginning of this chapter, but they seem to have entirely thinned out underneath the Wenlock rocks in their passage north and north-west, for nowhere in Merionethshire and Caernarvonshire are they found, while elsewhere in South Wales and the Longmynd and Shelve areas they form the lowest subformation of the Upper Silurian strata.

The apparent conformity between the Lower and Upper Silurian rocks of Merionethshire and Montgomeryshire (as I look at the subject) may be considered as an accident, and doubtless arises from the circumstance that during the deposition of the Upper Silurian rocks, the Lower strata of this particular area had been only slightly disturbed, when compared with the striking unconformity exhibited between the Upper Llandovery and underlying strata in Caermarthenshire, Radnorshire, and Shropshire, in one or other of which the Upper Llandovery rocks may be seen lying on the denuded edges of every formation from the lowest known Cambrian strata, across all the igneous interbeddings of the

* Six miles N.N.W. of Llanidloes, in Montgomeryshire.

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Caradoc or Bala beds.

Near Conway the members present are—

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Tarannon shale.
(*Upper and Lower Llandovery beds absent.*)
Caradoc or Bala beds.

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* Between Rhaiadr and New Radnor.

shale and Wenlock strata resting unconformably on the underlying formations, these so-called Llandovery beds may be overlapped. Following the edge of the Tarannon shales southward, they first appear in a very attenuated form about five miles south-east of Llangower near Bala Lake, on the south side of a fault that crosses Cefnbwlan from east to west. They consist of hard beds of grey grit, which thicken by degrees on their southward strike, and soon become intermingled with beds of shale. Throughout all their range of about 20 miles in a direct line to the river Tarannon,* they run in a narrow band, the lower edge of which is rarely more than half a mile from the shale, their thickness rising up to 500 or 600 feet. But east of the great synclinal curve on the Tarannon river the series increases to about 1,500 feet in thickness, and is repeated in a series of rapid contortions across miles of country between Careg-hir and Bryn-Crugog, in the manner shown in the following diagram, fig. 110.

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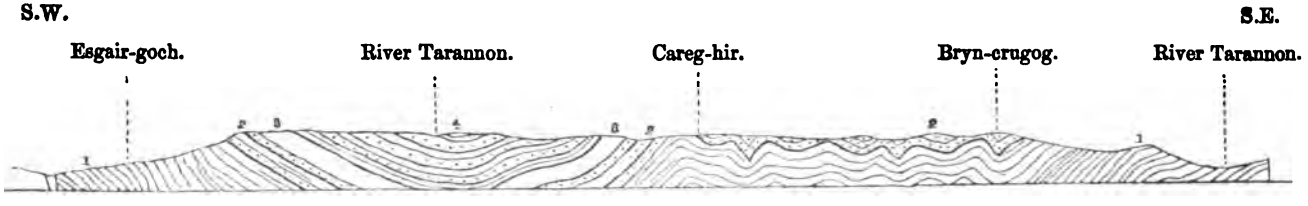
* Six miles N.N.W. of Llanidloes, in Montgomeryshire.

Fig. 110.

SECTION ACROSS THE LOWER AND UPPER SILURIAN ROCKS SOUTH OF LLANBRYNMAIR MONTGOMERYSHIRE.



1. Upper part of the Bala beds.
2. Lower Llandovery beds ?
3. Tarannon shale.
4. Denbighshire flags and shales (Wenlock).

volcanic series up to strata high in the Bala beds. At a later date the whole having been bent and contorted together, the strike of the Upper and Lower Silurian rocks here to a great extent coincides, although between them there is a decided break in direct sequence, marked not only by the absence of the Upper Llandovery rocks, but also by the decided manner in which the Tarannon shale overlaps a large part of the Bala strata, afterwards to be described.

Beyond a few rings of encrinites I do not remember that in this country any fossils have been observed in the doubtful Lower Llandovery beds, though near Builth and Llandovery, where they appear in force, they are highly fossiliferous.

Tarannon Shale.

The Upper Llandovery or Pentamerus beds being absent, the Tarannon shales in this district succeed the Lower Llandovery or uppermost Bala rocks, whichever they may chance to be. In mineral character they are, for the most part, very persistent, and consist of fine smooth slaty strata, grey or light blue, occasionally slightly sandy, and alternating with purple bands. They were first specially mentioned by Professor Sedgwick, who, I believe, called them "paste rock," from the circumstance that when decomposed they formed a fine muddy paste. No fossils have been found in them in North Wales, and they are interesting as showing how a new division, 1,000 to 1,500 feet thick, may be singled out between strata that were previously supposed to lie on each other without any break of succession. Till attempted by Mr. Aveline, no one thought of mapping these beds; and the proof he adduced in South Wales that they lie unconformably on the Lower Silurian rocks, and are overlaid transgressively, in much smaller degree, by the Wenlock strata, shows how necessary it is to map every possible formation in detail, before we can arrive at just conclusions respecting either the completeness or the fragmentary nature of the succession of strata; for here an independent sub-formation appears; and though in itself it as yet shows no fossils in North Wales, in thickness it is greater than the Wenlock shale at Wenlock, and probably occupied as long a period in its deposition.

Near Conway the Tarannon shale by unconformable overlap rests on a horizon of Lower Silurian rocks not much higher than the Bala limestone. From Conway to Llanbedr, about five miles south, these shales form a narrow band at the base of the Denbighshire grits, thrice interrupted by small faults, which are downthrows on the east. From Llanbedr all up the vale of Llanrwst and across the country beyond Pentre Voelas they are never seen. In the valley of Llanrwst they may underlie the alluvium, but it is more likely they are cut off by a large fault which, there is reason to suppose, under the alluvium, throws the Denbighshire grits against beds pretty low in the Bala series. Between the Vale of Llanrwst and the country four miles east of

Yspytty Evan and Pentre Voelas, except in one spot, they are nowhere seen in their natural position between the Bala beds and the Denbighshire grits; and it is presumed again they are cut off by faults, being downthrows on the north-east, west, north, and north-west. The evidence for the existence of these faults, lies partly in the fact that the Tarannon shale is so nearly conformable with the Denbighshire grits (or base of the Wenlock beds) that there is no reason to suppose it is anywhere suddenly overlapped. The nature of the conflicting dips also of the Denbighshire grits and adjoining Bala beds, and other circumstances well known to experienced mappers, left no doubt on Mr. Jukes's mind that these lines are actual faults, a conclusion in which I quite agreed even though the rocks of the country are, in places, much obscured by drift. Beyond this point they follow the winding western outcrop of the Wenlock beds, in a narrow band almost unbroken, from Merddwr, east of Pentre Voelas, to Llanddewi-Ystrad-enny, north of Builth in Radnorshire. First they strike east between eight and nine miles, and then bend suddenly round near Derwen at what may be called the north-eastern angle of the great Merionethshire anticlinal curve. Here for about half a mile they are cut out by two faults that meet in the form of a V and let in the Denbighshire grit, so that it is brought in immediate contact with the Bala beds. The Tarannon shale then strikes south-westerly for 8½ miles, when its continuity is broken by a powerful fault, which, on the north-east, as shown on the map, throws the whole Upper Silurian country, so to speak, forward more than a quarter of a mile, and which, if the result of a vertical movement, indicates a displacement of about 1,850 feet, the dip of the strata being between 45° and 50°.

The dislocation mentioned above is about 3½ miles north-east of Bala, and from this fault the same shales range a little west of south for nearly 30 miles to the high moorland of Tarannon, whence (being well developed there) these shales derive their name. Throughout all these long ranges the dip is so high that they strike straight across the country over hills and across valleys, being generally not more than an eighth of a mile wide, and rarely exceedingly half a mile. In Montgomeryshire, on and near the river Tarannon, the rocks being much contorted and denuded (see diagram No. 111, p. 288), wind about and run up the valleys of Nant-yr-Eira and Afon-Cwm-llwyd; and further north, from half a mile to a mile in width, they follow all the windings of the Wenlock shale, far beyond our present district, to the country near Builth and Llandovery, where they are seen to overlie the Upper Llandovery rocks or *Pentamerus beds* as these strata were originally called.

Denbighshire Grit and Wenlock Shale.

The Tarannon shale is succeeded by the more commonly recognized Upper Silurian rocks, which in Flintshire, Denbighshire, Merionethshire, and nearly the whole of Montgomeryshire, consist

of various representatives of the Wenlock shale, sometimes still preserving a shaly form; sometimes, as at Llangollen, consisting of truly cleaved slates and flagstones; and again, at its base in the west, represented by a vast thickness of interstratified shales and grits, named by Professor Sedgwick the Denbighshire grits and flagstones. A glance at the map will show their range in our present area. On the north, of enormous but unknown thickness, the Wenlock series, and possibly part of the Ludlow beds, forms the whole of that broad hilly tract that extends for 40 miles from the sea shores on the north of Denbighshire to beyond Llangollen, and from the Vale of Conwy to the Carboniferous limestone of the Vale of Clwyd. East of that valley, the same formation forms that long mountain barrier of which Moel Fammau forms the highest point.

I have said that an upper part of these widerspread strata east of the Conwy may possibly be Ludlow beds. In the Wenlock and Ludlow region the Wenlock limestone forms a good local line of division, but in the absence of that limestone in South Wales, no clear boundary line exists between Wenlock and Ludlow rocks either physically or palæontologically, and it is impossible to say that this is not the case on the broad hills of Denbighshire west of the Vale of Clwyd.

In the northern part of Denbighshire, of which Llansannan is the centre, few great high roads penetrate the Wenlock shale districts of the country; the hills, rarely bold, but high and steep, are yet of incessant recurrence; and thus it is that to strangers it forms the least known district of North Wales. Critically examined the ground is hilly in this sense only, that on a high table-land with an undulating surface, the rivers with all their numerous tributary rivulets, have scooped out a great number of steep-sided valleys, which run hither and thither to every point of the compass, and the old table-land has been changed into a wide tract of hills.

In the 1-inch maps, numerous arrows pointing in all directions attest the great amount of contortion and denudation that the strata, chiefly of rubbly shale, have undergone; a circumstance, joined to their thickness, that accounts for the great area which they cover.

Between Conway and the neighbourhood of Builth, a distance of 75 miles in a straight line, the Denbighshire grits, resting directly on Tarannon shale, form the western edge of the Wenlock formation. But thick as these grits are, in places at least 3,000 feet, and broad as the area is which they occupy, they form but a local variety of the Wenlock formation, and apparently, where the grits thin and disappear, instead of being overlapped by the shale, they rather pass by lithological gradations into strata of a shaly character. From the quantity of felspathic grains that enter into their composition, I am inclined to infer, that part of the mountain region of North Wales, between Conway and

Cader Idris, then formed land (very different from its present form), which, in some degree, contributed locally to make these strata by the waste of the felspathic lavas and ashes that form a distinguishing feature of the Lower Silurian rocks of North Wales. From east to west, and from north to south, the coarser gritty beds gradually disappear, the farther we recede from the larger centres of the Lower Silurian volcanic rocks. Near Montgomery and Welshpool they are unknown at the base of the Wenlock shale, though igneous rocks are near; south of the Berwyns they do not extend as far east as the base of the shale near Llanfyllin; and on the north of the Berwyns they are unknown. Neither north of Llangollen do they appear between the Tarannon and Wenlock shales that skirt the Bala beds of Cyrn-y-brain and Carn, a little south and south-east of the upper end of the Vale of Clwyd. The sand seems to have passed into mud going eastward; and the position of the above-named bosses of Caradoc or Bala beds leads to the inference, that much of the contorted Upper Silurian strata bordering the Vale of Clwyd on the west are not far from the base of the Wenlock shale, and belong to the horizon of the true Denbighshire grits that skirt the Vale of Conwy.

Vale of Conwy, &c.—East of the Conwy, nearly opposite the town, the Denbighshire grits and flags, much obscured by drift, occupy a space about three-quarters of a mile square. Their northern boundary strikes north-easterly, and though there seems to be a small intervening fault, which, by a downthrow on the south, cuts out the thin beds of Tarannon shale; yet, even allowing for that, it cannot lie much more than 800 feet above the calcareous sandstone that here represents the Bala limestone. This is a point of interest, for in part of the Bala country more than 4,000 feet of rocks lie between the limestone and the Denbighshire grits; and, making every allowance for thinning of the Bala strata, the difference helps to mark the extent of the overlapping unconformity of the Upper on the Lower Silurian rocks of North Wales. On the ground beyond the estuary, opposite Conway, they dip a little east of south at an angle of 55°, where on the east they are bounded by the Carboniferous limestone, and on the west the Denbighshire grits strike under water as if abutting on the Bala beds of Conway, helping to prove the continuation near the western side of the estuary of the line of fault that passes down the brook by Pentre-felin.* This fault being a downthrow on the east, casts the grits and shales forward to the north about three-quarters of a mile, and the amount of the throw is perhaps about 2,000 feet.

On the hill immediately south of Conway, the base of the grits, resting on a narrow band of Tarannon shale, strikes towards Gyffin, and from thence dipping east at angles between 10° and 35°, they pass southward by Y-Ro to Caerhun, when the western boundary is lost in the alluvium of the Conwy. There with their associated shales the grits form most of the hilly ground that stretches from Conway to Caerhun, half way up the river to Llanrwst.

Between the neighbourhood of Caerhun and Hendre-wen,† the west boundary of the gritty series is (under the alluvium) probably thrown down on the east against slaty and igneous rocks of the Bala beds, by the fault which there is reason to believe runs under the alluvium right along the bottom of the valley. East of the Conwy, at Pentre-felin near Llansantffraid-glan-Conwy, the Wenlock shale is thrown against the gritty beds by a downcast fault on the north-east, but within two miles of the river the dislocation passes into the shale

* Two and a half miles south-east of Conway.
† Two miles south of Llanrwst.

and is lost: and from thence the upper boundary line, which is rarely very definite, passes south, close by Eglwys-bach and Llanddoged and Llanrwst, where it rapidly curves to the south-east. With sundry undulations of the strata, which are most numerous near the north, the whole dips eastward, and passes upwards into the Wenlock shale; and, indeed, in all the tract that borders the Conwy, from top to base, shales in many places predominate.

South-east of Llanrwst the Denbighshire grits or flagstones occupy the whole of that barren and heathy range of hills that trends from the crags of Moel Saesiog by Mwdwl Eithin to Llechwedd near Cerrig-y-Druidion.* Though much of the ground is deeply covered by drift, there is little doubt that the lower boundary between Llanrwst and Merddwr, east of Pentre Voelas, is faulted against the Bala beds; but beyond this point to the angle of the Merionethshire anticlinal curve, near Derwen, the lower boundary striking eastward is tolerably distinct. On the range of hills mentioned above, the gritty beds, though interstratified with blue slaty shale, are often thick, and stand boldly out, their massive character having more strongly enabled them to resist denudation, thus giving rise both to the height and comparative ruggedness of the country. Here also, being partly repeated in three undulations, they spread across a space of six miles in breadth from Garn Brys to the grey rocks of Craigiau-llwydion beyond Llyn Alwen.

Approaching the sharp bend of the Merionethshire anticlinal curve, near Derwen, the undulations of these strata die out, and the total thickness of the grits on the banks of the river Alwen is compressed into a space of half a mile in breadth; and the beds now dipping steadily south-east from 30° to 50° must be about 1,500 feet thick. South of the Alwen they again widen out and occupy the chief part of the surface enclosed between the two great north-east faults and the fault that runs north-west from Llandderfel, near Bala. In the southern part of this area they lie in the form of a low synclinal curve, the east end of the grits being thrown by the great fault against an upper part of the Bala beds. A small patch overlying the pale-coloured Tarannon shale also forms the heights of Caer Drewgn near Corwen, and a continuation of the same mass separated by alluvium lies west of the town. On the hill it dips easterly under the ordinary Wenlock shale, and there dies out or passes into shale; for south and east of the Llansantffraid fault, though the Tarannon shale is present in a narrow band, no Denbighshire grit lies between it and the Wenlock shale all along the north side of the Lower Silurian boss of the Berwyns.

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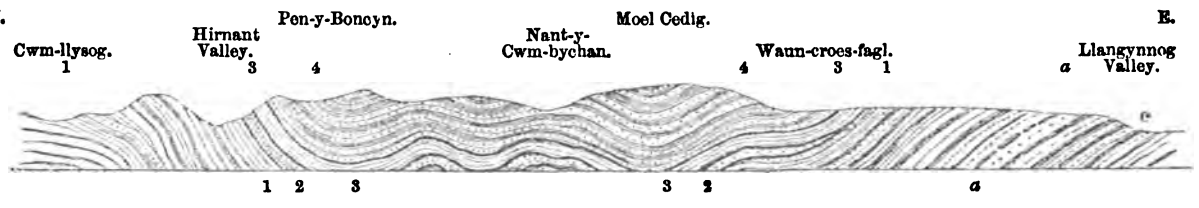
* Maps 79 S.W. and 74 N.W.

Fig. 111.

SECTION ACROSS THE DENBIGHSHIRE GRIT, TARANNON SHALE, AND CARADOC OR BALA BEDS, BETWEEN THE BERWYN HILLS AND THE COUNTRY EAST OF BALA LAKE.



1. Bala beds.
2. Lower Llandovery beds.
3. Tarannon shale.
4. Denbighshire grits and shales (Wenlock).

a. Bala limestone.
b. Hirnant limestone.
c. Felspathic ash.

Near Bala.—East of Bala and south of the Dee the Denbighshire grits form part of a trough about 14 miles in length, between the river and the road from Mallwyd to Welshpool. Passing south, it gradually increases from about 2 to 6 miles in width, the simple synclinal curve of the north resolving itself into several undulations, in one of which, about two miles west of Garthbibio, the Tarannon shale rises in an anticlinal curve, and is exposed at the surface in consequence of the removal by denudation of the previously superincumbent grit. On both sides of the synclinal trough the same Tarannon shale and the underlying Bala beds crop out to form the Bala country on the one side and the Berwyn Hills on the other, in the manner shown in fig. 111, drawn across the country about 6 miles south of the river Dee; but it will be observed that the so-called Lower Llandovery beds, No. 2, are represented as thinning away underground on the east, the meaning of this being that the Tarannon shale and Denbighshire grits are true Upper Silurian strata, and that they lie unconformably on the Lower Llandovery and Bala beds, part of which including these Llandovery beds seem to have been removed by denudation before the deposition of the Tarannon shale.

South of the Berwyn Hills the plications of the strata increase in number and become more complicated one result of which is, that the Denbighshire grits spread over a broad area between the hills east of Mallwyd and the neighbourhood of Llanllugan. In one of these contortions an outlier of the grits has been saved from denudation in the synclinal curve of Tarannor, in the manner shown in diagram No. 110 p. 282. The heart of this country is hilly, and broken by some noble heights, which generally with a bold western escarpment overlook the softer Lower Silurian shales. From this region the grits stretch far into Radnorshire, and thinning in some degree, finally disappear against a fault near Llanbadarn-fawr, north of Builth.

If we pass from west to east across any continuous tract of the Denbighshire grits where they are widest, it at first sight appears that they thin away or are overlapped by the Wenlock shale in the country north and south of the Berwyns; or, what seems more probable, and is, I have no doubt, the fact, that the gritty beds actually pass into true Wenlock shale by insensible lithological gradations. In Denbighshire, on Cyrn-y-brain and the smaller Lower Silurian patch south of the vale of Clwyd, Wenlock *shale* lies directly on the Tarannon shales that skirt the Bala beds. Along the north side of the Berwyn Hills, excepting near Corwen, the grits are absent and Wenlock lies directly on Tarannon shale all the way from Llansantffraid to the Carboniferous Limestone. South of the Berwyns, in the country west and south-west of Llanfyllin, the strata are much disturbed, and as we go from west to east the grits gradually become of less importance, and thin out or pass into shale on a north and south line about two miles west of Llanfyllin. Neither are they present at the base of the shale anywhere near Welshpool, Montgomery, Church Stretton in Shropshire, Builth, and the rest of South Wales. I believe, therefore, that these grits must not be considered in any way as an independent sub-formation, but are merely a western local sandy base of the Wenlock shale, formed by the denudation of Lower Silurian rocks during a slow submergence, while the deposition of the Wenlock strata was going on.

In some areas fossils are absent or very scarce in the Denbighshire grits, a few scattered rings of encrinites and ribs of bivalve shells alone showing that they are fossiliferous. At many points, however, fossils are sufficiently plentiful, such as we expect to find in the Wenlock formation.

About 3½ miles south of Conway, about a quarter of a mile east of Merchlyn-mawr, the more common fossils are, numerous fragments of the stems of an *Actinocrinus, Favosites ramulosa,* and *F. fibrosa;* the trilobites are *Phacops Downingiæ* and *Calymene Blumenbachii;* and the most plentiful Brachiopoda are *Rhynchonella nucula, Rh. borealis, Strophomena rhomboidalis, Chonetes striatella, Orthis elegantula,* and *Atrypa reticularis.*

At Plas Madoc, near Llanrwst, *in addition* to the above we have rings of *Encrinites, Cornulites,* and many *Tentaculites;* of trilobites, *Phacops caudatus, P. Downingiæ, Calymene Blumenbachii* and *Encrinurus punctatus;* and of Brachiopoda *Rhynchonella decemplicata, R. nucula, Strophomena pecten, S.*

rhomboidalis, Leptæna transversalis, Orthis elegantula, Atrypa reticularis, Spirifera elevata, S. exporrecta, Rhynchonella cuneata; of Lamellibranchiata, *Cucullella ovata, Modiolopsis* and *Ctenodonta;* and of univalves *Acroculia haliotis, Holopella gregaria, Murchisonia, Bellerophon carinatus, B. trilobatus, B. expansus;* besides an *Orthoceras*, and *Phragmoceras nautileum.*

Further east, on the high rocky ridge of Moel Seisiog and Mwdwl Eithen near Pentre Voelas, mixed with many of the species in the above lists, the following additional forms occur: *Favosites alveolaris* and *F. fibrosa, Syringopora serpens, Glyptocrinus, Homalonotus*, and a small species of *Pentamerus.*

North of this ridge, on Craig-hir, near the top of the gritty series, we have *Favosites alveolaris*, various *Encrinites*, including *Actinocrinus pulcher*, and the usual Brachiopoda, together with *Cucullella antiqua, Cardiola interrupta, Euomphalus, Loxonema elegans? Murchisonia Lloydii*, and *Orthoceras annulatum? O. primævum*, and *O. subundulatum.* In the same grits between the Bala country and the Berwyn Hills the same general list occurs. On and near Caerau Crwyni, south of the river Alwen, and further south on the hills round Pen-y-boncyn, in the valleys north and west of Llanwddyn, and along the course of the Twrch near Garthbibio, there were found plentifully, *Orthis elegantula, Atrypa reticularis, Rhynchonella nucula, Chonetes striatella, Spirifera elevata, Favosites fibrosa*, and fragments of the stems of *Encrinites.* The same general assemblage of species, in fact, appear in varying proportions all the way south to Bedd-Ugre in Radnorshire, and there is therefore no doubt that the grits form a true member of the Wenlock series. What remains to be said of these formations will be best described in the account of the general structure of the Berwyn Hills in the following chapter.

CHAPTER XXXI.

The Berwyn Hills.*

General Description.—The Lower Silurian rocks of the Berwyn Hills form an imperfect dome, or rather an irregular and broken curve, the anticlinal axis of which follows a bent line about 24 miles in length. The eastern end of this irregular dome-shaped mass has been cut away by denudation, and is overlapped by the Carboniferous limestone west of Oswestry. From the limestone the very irregular axis runs west by Llangadwaladr, Craig-y-Glyn, and Llangynnog, to the base of the Wenlock series, a little north of Garthbibio. Beyond this the anticlinal curve is lost or only faintly traced in the undulations of the Denbighshire grit and shale that form the broad hills south of the turnpike road between Mallwyd and Llanfair. The hills in this direction have sometimes been called the South Berwyns, and with the Northern Berwyns they form a watershed running west along the ridge of Mynydd Tarw to Cader Berwyn, from whence further west the watershed is the boundary between Merionethshire and Montgomeryshire on Craig-wen and Moel-cwm-sarnllwyd, and then striking southward it crosses Pen-y-boncyn and Moel-y-cerrig-duon to Carrig-y-groes, 4 miles north-east of Mallwyd. It is worthy of note in connexion with the physical geography of

* For all the passages in this chapter marked " " I am indebted to my colleague, the late Professor Jukes, who mapped the Lower Silurian rocks of the Berwyn Hills.

North Wales, that the drainage on the south and east of this line runs into the Bristol Channel by the Valley of the Severn; and all on the north and west, as far south as Moel-y-cerrig-duon, runs into the Dee; while the western drainage south of the same hill flows through the Dyfi into Cardigan Bay.

The general form of the Berwyn range is a curved ridge, convex to the north-west. Passing across the strata from north to south and from west to east the average slope gradually rises, not very steeply, to a height of 2,710 feet on Cader Berwyn, and 2,585 on Cader Fronwen, and these northern "and western slopes are "merely furrowed by such brooks as the Trystion, the Llynor, "and other small tributaries of the Dee; while towards the "south-east the mass is broken into many small hills and ridges, "separated by valleys running in many directions." Some of these ridges, above the recess of Llyn-llyn-caws and Cwm-maen-gwynedd, are almost precipitous towards the south and east, a result, taken in connexion with the faulting and older denudations of the strata, probably due to the soft dark blue slaty rocks of that area having been more easily wasted away, after the upper crusts of hard igneous rocks and Denbighshire grits were removed, by those exceedingly ancient denudations that seem to have planed across and levelled the tops of what are now mountains.

The internal structure of the Berwyn range corresponds to its external form. The position and lie of the beds of which it is composed may be described generally as an irregular oval dome, the side of which is continuous and unbroken on the north-west, but has been crushed in and shattered on the south, while the broken end is concealed on the east by the slightly inclined strata of Carboniferous limestone," already alluded to, "that have been "deposited, perhaps quite over the whole mass, and the denuded "remains of which, like a great scarped wall, runs north from "the Severn across the strike of the Silurian strata."

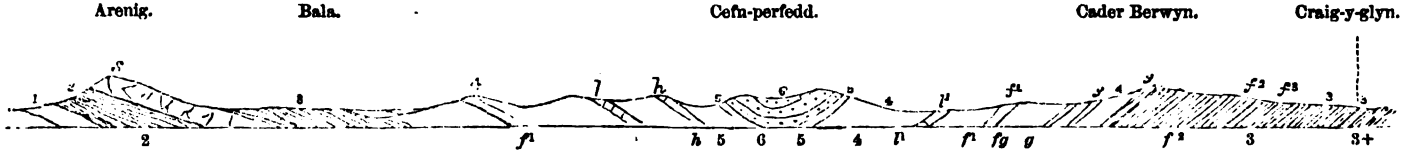
"We may best learn the nature and succession of the principal masses entering into the structure of the Berwyn Hills by traversing the country between Bala and Llangynnog, especially examining the neighbourhood of the Milltyr Gerrig pass, between Pennant and Llandrillo, and then studying the highest parts of the range and the ridges and valleys leading down from it to Llandrillo on the one hand, and to Llanrhaiadr-yn-Mochnant on the other."

The general result of such an examination is, that the Bala limestone and all its associated strata above and below plunge, from the Bala district at high angles to the east beneath the Tarannon shale and Denbighshire grits, in the manner shown in diagram No. 111, p. 288, and rise again with an opposite dip in the region of the Berwyns. Several sheets of sections of the Geological Survey illustrate this point,* which, if generalised and the faults eliminated, would give the result shown in diagram No. 112.

* Horizontal Sections, Sheets Nos. 31, 32, 35, 37, 38.

Fig. 112.

GENERALISED SECTION FROM ARENIG NEAR BALA TO THE BERWYN HILLS.



1. Lingula flags and Tremadoc slates.
2. Arenig beds.
3. Llandeilo beds and3 × Llandeilo limestone.
f. Felspathic lavas and ashes.
3. Llandeilo beds.
4. Bala beds, including f^1, upper Bala ashes; f^2 and f^3, lower ashes; *l* and l^1, Bala limestone; *h*, Hirnant limestone.
5. Tarannon shale.
6. Denbighshire grits
g. Greenstone.

On the far west are the Lingula flags and Tremadoc slates, No. 1, and Arenig beds No. 2 dipping east under the Felstone rocks, *f*, of the Arenigs, which in turn pass below the dark shales of the Llandeilo flags, 3. These dip under the Bala beds, 4, including the Upper Bala Ash, f^1, the Bala limestone *l*, and the Hirnant limestone *h*, overlaid by the Tarannon shale, 5, and the Denbighshire grits 6 lying in the form of a trough. On the east side of this trough, and indeed forming the lower part of it, the same Lower Silurian series rises, differing alone in details. The Hirnant limestone, which is very local in the Bala country, is absent in the Berwyns, but the Bala limestone, l^1, is present in force all along the western side of the Berwyn hills. Some depth below the limestone a bed of felspathic ash, f^1, crops out, about 300 feet thick, succeeded in descending order by other beds of similar rocks and of greenstone, *g*. These are the representatives, in greater force, of the thin ashy beds below the limestone east and north of Bala lake. East of and below Cader Berwyn the black shaly beds of the Llandeilo flags rise to the surface, the equivalents of those between Bala and Arenig; and beds of felstone, f^2, low in the series, though probably not identical with that of the Arans and Arenigs, lie apparently much about the same horison. Seemingly lowest of all, but on ground much broken and faulted, comes the Llandeilo limestone of Craig-y-Glyn,* overlying a bed of calcareous felspathic ash, which rests on blue slaty shales. The whole of these are probably the general equivalents of the calcareous ashes and slaty beds that underlie the felstones of Cader Idris, the Arans, and Arenigs. Nowhere, however, in the Berwyn country, does the section descend so low as the Tremadoc slates and Lingula flags, and therefore the equivalent of the Cambrian strata of Merionethshire and the Longmynd is also absent. Taken in connexion with each other, the three districts of Merionethshire, the Berwyns, and the Longmynd, form three mountain Lower Silurian bosses, partly formed of volcanic rocks, and between these there are two great synclinal bends; but in the middle boss, that of the Berwyns, the upward bend has not been sufficient to bring the Tremadoc slates, Lingula flags, and Cambrian rocks to a level where they might be exposed by the denudation of the overlying Silurian strata.

It is scarcely needful to remark that the fossils of the district agree with those of the corresponding strata in the Bala country. Thus, high above the Bala limestone of the Berwyn area on Cefngrugos, four miles north-west of Llanfyllyn, were found *Cheirurus clavifrons* and *Leptæna tenuicincta;* and on and about the horizon of the limestone west of Llanfyllin, and near Llanwddyn, the following species:—*Stromatopora striatella, Favosites fibrosa, Tentaculites anglicus, Asaphus Powisii, Trinucleus concentricus, T. seticornis, Phacops apiculatus, Ph. conicopthalmus, Calymene Blumenbachii, Beyrichia complicata, Orthis flabellulum, O. Vesper-*

* Two miles north of Llanrhaiadr-yn-Mochnant.

tilio, O. elegantula, O. porcata, O. spiriferoides, O. alternata, O. biforata, Strophomena tenuistriata, S. grandis, S. expansa, S. rhomboidalis, Leptæna sericea, Atrypa marginalis, Ctenodonta varicosa, Murchisonia simplex, and *Bellerophon nodosus.* The black slaty shales of the Llandeilo series east of the range of Cader Berwyn and south of Mynydd Tarw, have not been well searched for fossils, but in position and mineral character they resemble those just above and below the felstones of Arenig and Moelwyn, while in the limestone of Graig-y-Glyn itself there occurs plentifully the Landeilo species, *Asaphus tyrannus,* associated with *Trinucleus concentricus, Orthis turgida, Encrinites,* and *Cystideæ.*

Bala limestone.—I shall now explain the rocks of the Berwyn Hills more in detail, beginning on the west, availing myself for this purpose of the description supplied by the late Professor Jukes.

"The thin band of Bala limestone after plunging to the east in the Bala country, rises again to the surface near the summit of the Llangynnog road, close to the county boundary, just before descending the pass of Milltir-gerrig. In the year 1847 small quarries were to be seen in the limestone, which, with the adjacent slate rocks, dips westerly at angles varying from 30° to 50°.

Igneous rocks, &c.—"In the glen under Trwyn-swch, near this, a considerable patch of greenstone may be seen, being almost the only occurrence of igneous rock that I know in this neighbourhood so nearly on the horizon of the Bala limestone. Below this, crossing Craig-wen, and clearly visible on the road side of the Milltir-gerrig, is the band of rock answering to the Upper Bala ash bed. This, however, puts on here rather the character of a compact trap than an ash. It is a pale greenish-grey felstone, but acquires a much more brecciated and ashy character towards the south, while northwards it becomes, perhaps, still more compact and trappean, and increases in thickness.

"Some distance underneath this, another band of interstratified igneous rock makes its appearance, not very well seen in the road, but showing well on the tops of the hills at Postgwyn and the grouse box. This is believed to be the Lower Bala ash bed, but, like the former, it is much thicker than in the Bala district, and is seen near the grouse box on Craig-wen to be distinctly interstratified with apparently contemporaneous beds of dark greenstone. These coalesce and become very thick further north on Cefn Penagor, and in Clochnant on the northern side of the ridge sloping from Carnedd-y-ci.

"This ash ends, probably at a fault, to the south in the valley of the Eiarth, but is continuous to the east of Clochnant for many miles, gradually recovering its true form of an ash bed without molten traps.

"A third mass of contemporaneous interstratified rocks comes out from below the two mentioned above on the summit of Carnedd-y-ci. This is a peculiar ash resting on a thick mass of dark greenstone. The ash is quite compact and fine grained, not very hard, of a pale greenish-grey colour, with small dark specks, and is believed to be a greenstone ash*, in contradistinction to a felstone ash.

"The thicknesses of dark grey slate rock interstratified with all these masses, from the Tarannon shale downwards, is nearly as follows:—From the base of the Tarannon shale to the Bala limestone 3,000 feet, from the limestone to the highest ash bed 1,200 feet, from this to the second ash bed 2,000 feet, and from this to the greenstone ash 1,600 feet, in all 7,800 feet.

"If now we proceeded from the Carnedd-y-ci ash to the summit of Cader Berwyn, we should find that the dark earthy slates which we passed over dipped everywhere to the north-west at 35° or thereabouts, and consequently

* My former colleague, Professor Oldham, showed me, in London, in the winter after I had surveyed this district, a specimen of a precisely similar rock from Ireland, and asked me if I knew what it was; when I found that he had come to the same conclusion in Ireland that I had in Wales, namely, that this was a grenestone-ash.—J.B.J.

much more rapidly than the surface of the ground rose to the south-east. We should therefore pass over a considerable thickness of beds, from underneath which there comes out a thin band of greenstone, about 1,600 feet lower in the series, interstratified with, and apparently quite conformable to the slates, and striking north-east and south-west for about 2 miles.† It is apparently accompanied by a thin ash in part of its course.

"Another similar band of interstratified greenstone comes out lower down, the thickness of slate between the two being about 1,000 feet," giving, when added to the previous 7,800 feet, about 10,400 feet of Bala beds in all. "This lower band, which lies near the top of the Llandeilo series, is seen in the cliffs round Llyn-Llync-caws, and strikes thence north-east and south-west, being traceable for a distance of three miles. The dip of the rocks about this lower greenstone, however, is less than on the other slope of the range, as it varies from 20° up to 50°. If now we follow the brook that runs out of Llyn-Llync-caws, we shall find that the rocks still retain their northerly and westerly inclination till we arrive at the cliffs called Craig-poethion, and here we find another band of trap make its appearance, about 1,700 feet below the last, regularly interstratified with the slates, but of a pale greenish-grey colour and compact texture, being a felstone, like those of Arenig, &c.

"This trap may be followed over the ridges called Dol Drum and Godor, where other considerable masses of similarly bedded trap may be seen coming out apparently from beneath the slates which underlie the Craig-poethion trap, and 1,200 or 1,500 feet lower than the latter.

"Following the lower trap of Godor back to the Llyn-Llync-caws brook, it may be seen distinctly, opposite the waterfall of Pistyll Rhaiadr, dipping N.N.E. at 30°. Still lower down the brook, and therefore apparently still lower in the series than this trap, are other traps and ashes interstratified very distinctly with the slate rocks, and in some places well shown, but ending so abruptly and so obscurely among bogs and heather that it is impossible to speak with certainty as to their exact position or relations to the surrounding rocks. These are the traps stretching between Tan-y-ffordd and Gwern-feifod, and those running along the cliffs south of Foel-llyn, and traceable north of it towards Rhyd-y-gan.

"It is certain that the trap of Gwern-feifod is very low in the Berwyn series of rocks, and probably not far from the central nucleus of its dome-shaped elevation, and that it is nearly on the parallel of some of the very lowest of the lower trappean masses on the west side of the Arenigs.

"The whole district however is greatly cut up by large faults and dislocations. If we go to the foot of the fine waterfall called Pistyll Rhaiadr, we see an excellent exhibition of a contemporaneous felstone, rudely columnar, interstratified with the slates, and forming the cliff over which the water throws itself. In the adjacent cliffs two other parallel beds of trap may be seen above this, and may be traced across the brook above the waterfall. These three beds, however, seem to end abruptly at faults in each direction, though one of them is apparently continued at a rather different level, as the Craig-mawr trap on the south and that of Craig-poethion on the north. If now we start from the trap above the waterfall and ascend that brook, we find the beds dipping steadily to the west at about 20° till we meet with the lower greenstone (that of Llyn-Llync-caws) at its proper place, or where we should expect to find it, judging from its distance above the Craig-poethion trap. Thus far then all is regular. If, however, after following this bed of greenstone a little way to the summit of Bryn-mawr, we proceed still further west, scarcely half a mile, to Post-gwyn, we should come upon the Lower Bala ash-bed, the rocks in the intermediate space being seen to dip at no greater angle than 25°. But this Lower Bala ash bed is traceable to Clochnant, 3½ miles to the northward, and if from Clochnant we attempted to walk back to the nearest point of the Llyn-Llync-caws greenstone, we should have to pass over 2½ miles of ground

† It is often very difficult, if not impossible, to distinguish between a decomposed trap and an ash. In the case of the felstones, even the finely laminated or flaky structure may sometimes be deceptive, as some of the clinkstones of central France possess this character, and are in other respects very similar to some of the felstone and felstone ashes of North Wales.—J.B.J.

(as measured on a map) instead of half a mile, with the intermediate rocks dipping steadily to the north-west at angles of 20°, 35°, and 40°, instead of only 25°, and containing the Carnedd-y-ci ash and greenstone, the Cader Berwyn greenstone, and the thick intermediate slate bands between them. Of all these beds there is no trace, as indeed there is no room for them, between Bryn-mawr and Post-gwyn.

"The thickness of rock between Bryn-mawr and Post-gwn, calculated from the data there seen, would be about 1,100 feet, while that between Llyn-Llyncaws and Clochnant would be between 6,000 and 7,000 feet. The difference between these two figures (say 5,000 feet) would represent the thickness of beds wanting, that is, concealed by a fault, between Bryn-mawr and Post-gwyn.

"If we take it as proved that some large dislocation exists, and suppose it to run about N.N.W. and S.S.E., it will touch and account for the abrupt westerly termination of the Carnedd-y-ci ash on the north, and for the equally abrupt endings of other beds of ash, trap, and slate for several miles to the north.

"Now it is a good maxim to be as chary as possible in introducing a fault into any district, to avoid supposing the existence of one until it is either demonstrated or rendered so highly probable as to be hypothetically necessary. When, however, one large fault is thus proved, the existence of others almost follows as a matter of course, since it is scarcely possible, physically, for a single large fracture to traverse a mass of rocks and produce great dislocation, unaccompanied by others neighbouring to it and connected with it.

"If, then, we hold it allowable to account for the abrupt termination of the beds above mentioned on one side by means of a fault, it is equally allowable, and indeed necessary, to draw a fault along the other ends of these beds; that is to say, along the ends of the Carnedd-y-ci ash, the greenstones of Cader Berwyn and Llyn-Llync-caws, and the traps of Godor, and the slate beds with which these are interstratified. All these beds end abruptly along the southern bank of the valley of the Iwrch; while to the north of that valley all the rocks of the ridges of Y Foel-wen, Mynydd Tarw, and the country around Llanarmon Dyffryn Ceiriog, appear to be composed of the black slates which lie above the Cader Berwyn greenstone, variously crumpled and rolling about. Between these two main lines of fault, running nearly parallel north-west and south-east, but slightly diverging in the latter direction, there appears to be another parallel to them running down the valley of the Rhaiadr from the neighbourhood of the waterfall, and many other minor dislocations crossing and connecting these in various directions.

"The traps of Craig Rhiwarth, just north of Llangynnog, are felstones, in some places distinctly interstratified with the beds of slate, while in others they form great shapeless masses, ending abruptly and without showing their relations to the surrounding rocks. The lead lodes for which the district was celebrated run nearly east and west, and form a portion of the dislocations by which it is traversed, many other faults being traceable by means of the sudden termination and broken endings of the different masses of rock of which the country is composed.

"The hill of Y Garn, east of Craig Rhiwarth, is similarly composed of trap and slate, which may be seen in places distinctly interstratified, while their relations in others are obscure and their boundaries uncertain.

"On the opposite side of the valley of the Tanad is a mass of hills, part of which is called Cyrnia. Along the southern side of these hills the slates are regularly interstratified with felstone ashes or traps. These beds are very regular, dipping south at a high angle about Peniarth, at the eastern end of the hill, and are equally regular in many places all the way along by Craig-ddu to its western extremity. There are, however, places about Craig-ddu where the position of the beds is so discordant to the rest, and the change of dip and strike so frequent, sudden, and irregular, that it was found to be impossible, with the small scale of the one-inch map, to disentangle the confusion. Many large faults must exist, one at least of which contains lead ore, and is, or was, worked with profit.

"The eastern extremity of these beds is supposed to be cut off by the main fault first described, coming down from Bryn-mawr, and this appears to run still further south through the ridge of Dâs Eithin, where it was found formerly

to contain lead ore. At this extremity of its course, however, the beds are vertical, or nearly so, and therefore no lateral shift is produced by it at the surface."

Limestone.—"Let us return now to the band of Bala limestone, with which we commenced our description, on the road above the Milltir-Gerrig pass. This little band of limestone, with the larger and more prominent ash bed about 1,000 feet below it, are traceable southwards at short intervals, wherever the rocks appear from under the peat, heather, or soil with which they are covered, down into the pretty little valley of Pennant, and thence for four miles, across wild moors and hills, to the larger and more open valley of Llanwddyn. They are here thrown into the form of a sharp and distinct anticlinal curve, the axis of which runs about N.N.E. and S.S.W., sloping or declining towards the south. One side of the point or 'nose' of the ash bed just comes across the river Fyrnwy, being seen under the farm-house called Bryn-du, about 2 miles below the village of Llanwddyn. From the other side of the river the two ribs of ash run continuously northwards, but gradually diverging from each other as the anticlinal spreads owing to the rise of its axis. The beds on the west side dip to the west at angles of about 20° or 30°, while those on the other slope dip east and south-east at angles of 75° and 80°, increasing up to 90°, and eventually being inverted to the amount of 10° beyond the perpendicular, and dipping north-west, or toward the axis, at 80°," and this reversed dip of the Bala beds, both below and above the limestone, of the Denbighshire grit and the overlying Wenlock shale continues on a north-east strike for a distance of about ten miles, all the way from the neighbourhood of Garthbibio (Map 60 N.W.) to the country two miles south of Llanrhaiadr-yn-Mochnant (Map 74 S.E.).

"The southern termination of the limestone at the surface, as it crosses over the anticlinal ridge, may be seen in the little valley of the Conwy river, about 3 miles south of Llanwddyn (Sheet 60 N.W.) A little above Pont-y-Llwynog a thin band of dark limestone and calcareous slate may be traced across the brook, dipping S. 10° W. at 35° on the south side of the river, where it suddenly ends, and curving round higher up till it dips west at 30°, and then strikes off north of Llanwddyn.

"In the other direction its continuation was found to be thrown by a fault nearly a quarter of a mile to the south, being found just south of a farm-house called Ffrith-Conwy, dipping south at 60°; from which place it strikes off north-east, and is seen again in rather a debased form at about a mile distance just east of Ty-newydd. It here dips N. 30° W. at 75°, being affected, along with all this band of country, by the inversion of dip mentioned before.

"The limestone then assumes the form of a calcareous sandstone rather than of a true limestone, but may be traced at intervals, accompanied by phosphatic matter close on the S.E.,* running in a straight line north-east for 6 miles to Wern-y-scadog, and the road between Llanfyllin and Llangynnog. For the details of the structure of this district I must refer to the maps (Sheet 74 S.W. and 60 N.W.), but would add that the interest to be derived from the study of a locality in which so many and such various physical features are so admirably shown, is heightened by the fact of the limestone and parts of the ash beds and all the beds about them being crowded with a vast variety of fossils, containing, I believe, all the characteristic species of the formation, and generally in a well preserved condition.

"From this corner of the Berwyn district, where the rocks are pinched up into an anticlinal, forming, as it were, a tail to the dome-like elevation, the upper beds open out towards the north-east, and allow of the appearance from beneath them of the lower beds about Llangynnog. It is remarkable, however, that on the south-east side the ash dies out very soon, simultaneously indeed with the change of the beds about it into a sandstone, and the limestone itself becoming arenaceous.

"If we follow these rocks eastward towards Llanfyllin, the whole of the Bala beds are found to acquire a strong arenaceous character, and to resemble the

* This phosphatic matter was not observed when the country was surveyed, but it has lately been discovered, and promises to be of much value, containing in some cases, according to Dr. Voelcker, from 48 to 64 feet of phosphate of lime.

Caradoc sandstone of Shropshire rather than the beds about Bala. So strongly were Mr. Aveline and myself impressed with this, that we sent a box of specimens to Professor Forbes to know if they were not Caradoc fossils. He replied that they were all Bala species, but this prepared me to receive the statement that the Bala and Caradoc rocks were the same.

"The rocks around Llanfyllin generally strike east and west, but are thrown into such a number of rapid folds and convolutions that it is impossible to follow any one bed or to trace any one horizon through them, seen, as they are, only in detached quarries or small natural sections.

"I have sometimes thought it possible that the ash beds of Craig-ddu and these hills south of Llangynnog might be the Bala ash repeated by sharp folds and dislocations.

"The ridge of Craig-y-gorllwyn, again, 2 miles east of Llanrhaiadr-yn-Mochnant, contains a strong thick well-marked ash bed running unbroken nearly 2 miles, and so like one of the Bala ash beds that we were strongly tempted to consider them equivalents.

"It dips S.S.E. at 45°, and therefore it plunges under all the fossiliferous sandstone country south of the Tanad in which the Bala limestone ought to lie, but its relations to the limestone of Craig-y-glyn is uncertain.

"Between the Craig-ddu ridge (south of Llangynnog) and that of Craig-y-gorllwyn there is a gap in which neither limestone nor ash has been found near their regular strike, but 2 miles north-west of this strike, in the valleys of the Rhaiadr and Iwrch, detached fragments half a mile or more in length of a limestone, resting on a bed of gritty ash, not very unlike the Bala limestone, make their appearance. They gave me at the time the notion of their being detached portions of the Bala limestone thrust bodily thus far from their original place by the action of the great central dislocations mentioned before, and let down as it were into the heart of the lowest rocks of the central mass of the dome-like elevation.

"One of these masses of limestone may be seen at Gorwyllt, on the south side of the valley about 2 miles above Llanrhaiadr-yn-Mochnant. It dips S.S.E. at 85°, resting on a gritty ash bed ending one way in the Rhaiadr, and in the other direction in a brook against some black slate which dips N.W. at 10°.

"The other and more considerable patch of limestone is at Craig-y-Glyn, a little more than a mile north of Llanrhaiadr, where the limestone likewise rests on a bed of ash, and these two pieces of limestone are doubtless part of the same bed.

"It appears, however, from the fossils it contains that the Craig-y-Glyn limestone is not the Bala but the Llandeilo limestone, and that it must, if anything, be brought up by the faults from below rather than be let *down* from above.

"Leaving now this dislocated centre, and again returning to the point where we commenced, on the road above Milltir-gerrig, let us follow the upper beds to the north and east. In doing this we shall have as much reason to be struck with their steadiness and regularity as we have just had with the confusion of the central district.

"From the summit of the ridge called Craig Wen and Pen-y-bryniau the whole of the beds strike regularly north, dipping west at angles varying from 20° to 35°, in the manner shown in fig. 111, and in a more generalised form for all the strata of the district in fig. 112, p. 292.

"These as they approach Llandrillo curve gently and steadily round towards the east till they strike due east and dip north at angles of 15° and 20.° This east and west strike is steady for a distance of 8 miles to the valley of the Ceiriog between Llanarmon-Dyffryn-Ceiriog and Llansaintfraid-glyn-Ceiriog, beyond which it curves a little to the south, and the beds strike E.S.E. towards Selattyn, till they are covered and concealed by the Carboniferous limestone and Millstone grit, which run north and south right across them. The Bala limestone indeed is not at all continuous, or, if so, is not visible throughout the whole of this sweep. Calcareous and concretionary beds that doubtless represent it may be seen a little above the road between Craigiau-duon and Blaendinam, about 1½ miles S.S.W. of Llandrillo. Similar calcareous bands may also be seen about 2 miles east of Llandrillo, in the gullies of Nant Brian and Nant Gwynn, just south of their junction.

"With these exceptions, nothing was to be seen of the limestone till we reached the Ceiriog, south of Llansantfraid, though the fossils were found abundantly at intervals in all the beds near its margin.

"Just south of Llansantfraid Glyn Ceiriog, two bands of limestone make their appearance, of which the lower one is doubtless the true representative of the Bala limestone. They are well seen, having been quarried and burnt for lime, and, together with the beds of slate in which they lie, are full of the Bala fossils.

"It would appear from the position of these beds, with respect to the Upper Silurian beds north of them, that the Upper must be unconformable to the Lower Silurian formation."

Ash Beds.—"The Upper Bala ash bed, so well shown in the anticlinal east of Llanwddyn (Sheet 74 S.W.), and so clearly traceable from it to the northwards by Moel-di-Moel, Craig-y-Castell, and the crags over Blaen Rhiwarth, assumes thence, as has been before stated, the character of a trap rather than an ash. From Craig-wen to Tyn-y-nant it is a smooth compact felstone, with small dispersed crystals of felspar. About a mile south of Llandrillo another thin band of ash may be seen coming in over it, and this, which we called the Little ash, is traceable thence for 8 or 10 miles to the eastward. After passing over Trum-y-wern, the Upper Bala ash re-assumes its normal ashy character, and together with the Little ash bed forms conspicuous crags in all the gullies and ravines, and often as conspicuous ridges along all the escarpments which it traverses, from Pont-rhyd-y-rhyd to the Ceiriog, south of Llansantfraid, and the escarpment of the Carboniferous limestone.

"The Lower Bala ash bed is well seen on Post-gwyn, where it consists of greenstone ash at top, with coarse ash below, and a bed of greenstone under that. At the Grouse Box, on the ridge to the north of Post-gwyn, a thickness of about 200 feet of alterations of two beds of greenstone with greenstone-ash may be seen; and further north the two beds of greenstone coalesce into one strong bed which runs thence regularly round into Clochnant, and after crossing the ridge called Trawsnant, gradually thins out and dies away south of Hafodty-llynn. The ash over this greenstone is of that peculiar fine-grained smooth texture and greenish grey colour with dark specks that is characteristic of greenstone, and it retains that character for some distance to the eastward of the watershed as far as the valley of Nant Rhyd-wilym. It gradually gets coarser to the east, however, and assumes the form of a coarse flaky ash like the Upper ash, which it follows persistently and with similar features across the country by Craig-fawr, and Moel-ewig, and Pen Llyn-gloyw, to the picturesque little valley of the Ceiriog so often spoken of before. } Pontysgh.

"From this point it is still distinctly traceable by the cliffs south of Gwastadmawr to Llechrhydau and the woods of Cefn-coch, where in some places it is associated with beds of felstone containing crystals of pink and green felspar. It seems to be getting thicker too and more important, but at 'The Springs' is finally covered by the Mountain limestone.

"Parallel to these long continuous bands of ash, and from 500 to 1,000 feet beneath them, is a little bed of greenstone, lying in the plane of the slate beds, and nowhere producing any great alteration nor any disturbance. It is about 20 or 30 feet thick, and stretches from Cwm Llawenog, through Mynydd Bach, north of Llanarmon, to Pen-y-gwely, a distance of 7 miles. It appears to die out in each direction, and may be either a representative of the Carnedd-y-ci or Cader Berwyn greenstone, more probably the former.

"From beneath this again came out the dark slates and gritstones of the Llandeilo flags, making the ridges of which Mynydd Tarw is the chief, the beds still dipping generally to the north at angles of 30° or thereabouts, and striking to the east, in which direction they pass into some singular black sandstones about Craig-yr-hwch, Bwlch-y-domgay, and Allt-y-gwrach.

"Perhaps still lower beds may come out in Mynydd Mawr and Gryn Moelfre, but this is very doubtful; and the absence of any appearance of trap of any kind between Llanarmon-Dyffryn-Ceiriog and Llanarmon-Mynydd-mawr, Llangadwaladr and Llansilin, makes it probable that this district is occupied by the black slates lying above the traps, those forming the western slope of Cader Berwyn or the neighbourhood of Llyn Llync-caws.

"Traps and ashes, however, make their appearance in considerable force in the south-east corner of the district, coming out from under the Carboniferous

limestone in four irregular patches at Pwllau-meirch, Tre-arglwydd, Ffynnon-dêg, and Blodwel Hall. These in some places consist of felstones or greenstones of a massive character, in others of regularly bedded ashes, sometimes interstratified with the slates. Some of these contain crystals of pink felspar, and otherwise resemble the Lower ash bed as it appears a few miles to the northward at Llechrhydaw and Cefn-coch; and it is probable that a considerable mass of igneous rocks belonging to the Silurian formation may be concealed under the Carboniferous beds to the east, with which the Lower ash bed was connected."

Summary.—The result of the foregoing description is, that in the Berwyn hills there is a repetition of the rocks of Bala and the country to the west as low as the Llandeilo beds, but that in the Berwyns the lowest strata most nearly resemble the Llandeilo limestones of South Wales, and none of the older strata from the Arenig beds downward rise to the surface in what must be considered as the central point of the anticlinal dome about 2 miles north of Llanrhaidr-yn-Mochnant. Of the interbedded igneous rocks, the two highest represent the ash beds of Bala and the great contemporaneous felstone and ashy beds of Dolwyddelan and Snowdon. Probably, indeed, they are nearly precise equivalents. The lower bedded greenstones and felstones are the general representatives of the great semicircular group of igneous rocks that range from Cader Idris by the Arans, Arenigs, Manods, and Moelwyn, to the neighbourhood of Tremadoc; but in the Berwyn country they are much thinner and less varied than in Merionethshire. The total thickness of the strata is as follows:—

	feet.
Bala beds above the limestone, about -	3,300
„ below „ about	4,500 to 4,800
Llandeilo beds, about - - -	4,500

making 12,300 feet of Lower Silurian strata, exclusive of the Arenig beds and all below.

CHAPTER XXXII.

Upper Silurian Shales and Flagstones of Denbighshire and Flintshire, Old Red Sandstone, and Carboniferous Limestone, Vale of Clwyd.

Boundaries of the Upper Silurian Rocks, and Carboniferous Limestone.

General Description.—I have already mentioned the lower edge of the Wenlock shale where it overlies the grits of Denbighshire, from the mouth of the Conwy to the country near Corwen, and from thence along the northern flanks of the Berwyn Hills. It now remains briefly to notice its upper boundary and the interior of the country formed of Upper Silurian rocks in Denbighshire. On the right bank of the estuary of the Conwy, opposite the town, they are bounded on the north by the Carboniferous Limestone of the district of Creuddyn, which there, on the heights of Gwylfryn and Bryn Eurian, dips northerly and forms a bold

escarpment that overlooks the hollow of Llangwystenin, striking out to sea on the north-west side of Rhos bay. Curving round (probably immediately beyond the shore), the limestone again touches the coast near Colwyn, and its base strikes for about two miles to the south-east, resting on a band of Upper Old Red Sandstone, conglomerate marl and cornstones, which unconformably overlies the Wenlock shale. The same arrangement, interrupted by a fault, continues as far as the neighbourhood of Twll-llwynog, on both sides of the opening of the valley that passes down to Abergele. Beyond this the limestone seems to be thrown against the Silurian strata, but the ground is much obscured by drift. On the opposite side, at Plas-uchaf, the Old Red Sandstone again crops out, and lying on the Wenlock shale shows itself in a narrow strip to Ddol, where the Elwy breaches the limestone.

Along the western edge of the limestone south of the Elwy the Old Red Sandstone is occasionally visible as far as one mile S.E. of Henllan, where it is cut off by a north and south fault for a distance of nearly a mile. On the east side of this fault it is seen in the bed of the brook about half a mile S.W. of Denbigh Castle, cropping out from beneath the Carboniferous Limestone of Galch Hill, and it is believed to occupy a similar position with relation to the limestone of the Castle, and to extend as far east as the north and south fault that runs through the town of Denbigh.

The same beds were found in excavating the reservoir of the waterworks, but are not seen again as far as Pandy, about a mile south of Llanrhaiadr.

A large fault runs south from Llanrhaiadr, throwing the strata down on the east, so that for a space the New Red Sandstone abuts directly against the Silurian rocks. Where on the east side of this fault the base of the limestone again appears it is underlaid by the Old Red Sandstone, a good section of which is seen in the valley of the Clywedog. Beyond this it is exposed near Llanfwrog, and further south at the foot of the steep escarpment of limestone through which the Ruthin and Corwen Railway passes.

Throughout all this tract, from the neighbourhood of Colwyn by the sea to near Ruthin, these narrow strips of Old Red rocks seem to form part of the same set of strata as the Old Red Sandstone of Anglesey, and both belong to that upper division of the formation which both here and elsewhere shows a connexion with the Carboniferous Limestone.

South of Ruthin the bold Carboniferous Limestone escarpment of Coed Marchan and Craig-y-adwywynt overlooks the Wenlock Shale, the limestone dipping east at angles varying from 10° to 20°. At its south end the strike of the strata suddenly bends round to the east and north-east, a change which is accompanied by a complication of faults. The principal of these is an east and west branch of the great Bala fault, which being a downthrow on the north, throws the limestone against the Wenlock Shale and the shale against the Bala beds on the north side of Cricor-mawr.*

* Six-inch Sections, sheet 38, line 6.

The limestone, about 1,000 feet in thickness where exposed, dips at an angle of about 40° to the north, resting quite unconformably on the Wenlock Shale. This unconformity is obvious all along the line above described, from the mouth of the Conwy to the south end of the Vale of Clwyd, a distance of about 30 miles. Wenlock Shale, Old Red Sandstone, and Carboniferous Limestone all dip, as a whole, north-easterly; but whereas the dips of the Old Red beds and of the limestone are steady in their direction, at angles of from 8° to 20° and 25°, the Wenlock strata lie at all inclinations up to 65°, and frequently the beds strike towards the newer strata or dip away from them close upon the points of junction.

The rocks on the eastern side of the Vale of Clwyd are all affected by a great fault which extends from the neighbourhood of Prestatyn to the upper end of the valley.

Along this line of fault the Carboniferous Limestone is seen here and there in a few narrow strips between the New Red Sandstone that forms so much of the bottom of the Vale of Clwyd and the flanks of the Silurian hills. From the point where the limestone curves round at the south end of the valley, it first strikes north about a quarter of a mile in width for three miles, forming the prominent ridge of Y-Graig-wyllt. It is then lost for a space under the New Red Sandstone, but again shows itself in a little patch east of Llanrhydd. A second occurs south-east of Llanbedr; and a third, more than a mile, in length lies S.S.E. of Llangynhafal (Fig. 113, No. 3. W. of Moel Fammau). A fourth, about two miles in length, lies east of Llangwyfen, and it again crops out for a short space at Bodfari. Beyond this it rises on the hills immediately north and south of Tremeirchion, but is not seen again on the western side of the Silurian hills.

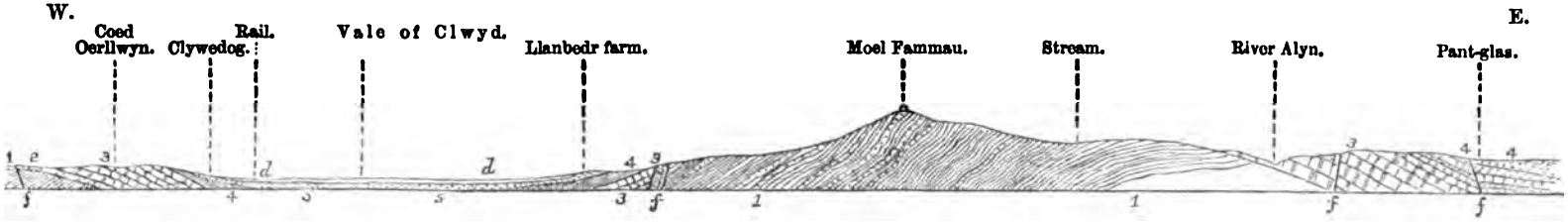
All along this range, of about 20 miles in length, the limestone, with some beds of red sandstone and shales, dips westward, at angles varying from 10° to 50°. The Wenlock Shale lies on the east side of the fault, and rises quite unconformably from beneath the limestone at Tremeirchion, forming the fine range of lofty hills that stretches from the valley of Bryn-Eglwys on the south to Cwm, east of Rhyddlan. The loftiest hill in this range is Moel Fammau, which rises 1,823 feet above the level of the sea.

In the first edition of this book I accepted the opinion of Mr. Maw of Benthall Hall, that three very small patches of red sandstones and shales, one near Pentre-methiant and Llanfair Chapel, and others at Llangynhafal and Llangwyfen are of Permian age.* Further experience has led me to change that opinion, and to consider as Mr. Aveline and myself originally supposed, that these red sandstones and shales truly belong to the Carboniferous series stained red by percolation through the New Red Sandstone of water bearing iron in solution, before part

* Llanfair Chapel is near the south end of the Vale of Clwyd; Llangynhafal and Langwyfen on the east side further north.

Fig. 113.

SECTION ACROSS THE UPPER SILURIAN ROCKS, OLD RED SANDSTONE, CARBONIFEROUS LIMESTONE, MILLSTONE GRIT, AND NEW RED SANDSTONE, OF THE VALE OF CLWYD AND ITS NEIGHBOURHOOD.



1. Upper Silurian rocks (Wenlock).
2. Old Red Sandstone.
3. Carboniferous limestone.
4. Millstone grit and purple sandstone.
5. New Red Sandstone.

d. Drift.

f. Faults.

of these New Red strata were removed by denudation from above this portion of the Carboniferous rocks. This phenomenon is frequent along the eastern and upper boundary of the coal-measure shales and sandstones of the Nottingham and Yorkshire coalfield, and this accident originally led William Smith to consider these red-stained strata as belonging to beds directly connected with the Magnesian Limestone now called Permian, and long after his time they were still considered to be of Permian age. This mistake has been long since abandoned.

These red, or rather purple, sandstones have now been found to crop out at intervals more or less all round the valley on both sides. They rest conformably on the limestone, but are overlapped repeatedly by the New Red Sandstone which lies quite unconformably upon them. They are best exposed on the banks of the Elwy near Glan-llyn, again about a mile south of Denbigh lying on the limestone near Pont Ystrad, also in a dingle near Pont-cerrig, and at the extreme south end of the valley. On the east side of the valley they are exposed on the high road west of Dyffryn Clwyd, and for a distance of more than three miles between Llanbedr and Llangwyfen, and also near St, Asaph on the bank of the Clwyd a quarry long since abandoned was formerly worked. Traces of the same strata occur near Rhiallt on the Holywell and St. Asaph road.

On the authority of Mr. Strahan, who has partly remapped the country, these purple strata are the equivalents of the base of the Lower Coal-measures, or the upper part of the Millstone grit of the neighbourhood of Mold, as shown in an old quarry near Maesgarmon, where they possess the same lithological character and are distinguished by the same purple hue.

The range of Moel Fammau.—Between Pentre-bach, near Diserth, and the neighbourhood of Tommen-y-Rhodion, near Llandegla,* the Carboniferous Limestone bounds the Wenlock Shale of the Moel Fammau range on the east (Fig. 113). The line forms a great irregular curve about 22 miles in length, passing from Moel-hiraddug on the north, to the country a mile west of Caerwys, then S.E. along the slopes on the north side of Afon Chwiler and by Cilcen and Llanarmon to a sudden bend in the Ruthin road, where, near Penant-isaf, it is thrown down against the Wenlock beds by a branch of the Bala fault. Here and there the continuity of its base line is broken by small faults, some of which, between Cilcen and Llanarmon, are lead veins, which lose their value as they pass from the limestone into the Wenlock shale. As a whole, the limestone, in long terraced lines, dips east at comparatively low angles (15° to 20°), forming gentle slopes, while the western escarpments form comparatively steeply sloping hills. The Wenlock Shale, on which it rests quite unconformably, rises from underneath with a high and irregular yet sweeping outline. The sides of the long range are scarred by many valleys, and altogether its heights form a marked contrast to the tamer

* About 10 miles in a straight line west of Wrexham.

slopes of the Carboniferous rocks lying on the east at lower levels. (No. 1, fig. 113, Moel Fammau.)

Though the Upper Silurian rocks are occasionally somewhat contorted, the prevalent dips are to the westward at all angles ranging up as high as 70°, so that the outcrop of the lowest beds of Carboniferous Limestone on the east side of the range probably lies almost on the base of the Wenlock Shale.

The general result of the disturbances that produced the present arrangement of the strata is shown in fig. 113, which is typical of other parts of the valley. No. 1 represents the Wenlock strata which dip westerly on both sides of the valley. No. 2 the Old Red Sandstone, which is absent on the east side of the valley. Nos. 3 and 4 the Carboniferous Limestone and Millstone Grit and purple sandstones, which dip east and west on either side of the valley underneath the New Red Sandstone, which therefore lies in a trough of unknown depth.

Llangollen.—South-east of the Vale of Clwyd, between the Bala beds of Cyrn-y-brain and the Berwyns, the Wenlock beds fill a space about 6 miles broad, consisting of steep-sided flat and round-topped hills, intersected from east to west by the river Dee. Numerous tributary valleys branch north and south from the river into the heart of the hills.

The well known slate quarries near Llangollen are therefore worked in rocks of the age of the Wenlock Shale, curved and contorted, well consolidated, and traversed by true slaty cleavage. Where the bedding and cleavage chance to cross each other at angles much diverging, the quarried masses split into excellent slates, and when cleavage and bedding chance to coincide or nearly coincide, into valuable flags often of great size. On the east, between Craig Arthur and Ty-uchaf,* the Old Red Sandstone rests unconformably upon it. From thence to Tan-y-Castell† a fault passes from Y-fron-fawr to the south-east, and throws first the Old Red Sandstone and then the Carboniferous Limestone and millstone grit against the Wenlock Shale above the river Dee to a point 4 miles east of Llangollen.

West of the Vale of Clwyd.—I have already described the Upper Silurian rocks that lie west of the Vale of Clwyd, which present in part the same kind of physical features that mark the rocks on either side of the Vale of Llangollen. A wide tract of high hills strikes westward from the upper part of the valley towards Yspytty Evan and Llanrwst. The average dip of the strata being north-east, the range of hills of which Mwdwl Eithin is the most prominent, is apt to be scarped towards the south, and their height is partly due to resistance to waste, because of the hardness of the Denbighshire flagstones and grits that here form the lower part of the Wenlock strata.

The chief drainage of this country flows northward through a perfect network of valleys, and gradually uniting to form larger streams, the water at length finds its way into the river Clwyd

* About 2 miles north of Llangollen. † 1 mile north of Llangollen.

through various gaps in the limestone rocks that flank the Wenlock Shale on the east. I know of no better area in Wales than this part of Denbighshire by which to prove the effects of running water in cutting out in an old table land a labyrinth of valleys, sometimes shallow, sometimes deep and steep-sided. The whole country in fact is intersected by valleys so numerous and comparatively so steep on the sides that there is scarcely any part of Wales more difficult of access than this part of Denbighshire. It is essentially a rural district, without large rivers, without many mines or centres of trade, and even without villages or market towns of any importance, in an area of about 25 miles in length and from 6 to 14 in width. The very roads convenient for driving are, or at least used to be, few, and over large areas you might walk faster in the heart of Denbighshire than you can drive.

A long band of sandstone lies in the heart of the country, but the rest of this part of Denbighshire is shaley and flaggy, with a tendency to become sandy in the higher strata, some of which may belong to the Ludlow rocks. The scarcity of fossils, however, and the absence of dividing beds of limestone, such as occur in the Wenlock and Ludlow country, renders this very uncertain. Near Corwen the shaly and concretionary character of about 1,700 feet of rocks at the base, and further east and north the flaggy and sometimes sandy nature of about 3,000 feet of higher strata, agrees tolerably well with somewhat similar developments of the Wenlock and Ludlow beds between Builth and Llandovery in South Wales.*

In Denbighshire, fossils have chiefly been found in the lower part of the series in dark blue or blackish shale. They chiefly consist of thin-shelled *Orthoceratites*, *Orthoceras primœvum and O. ventricosum*, with *Cardiola interrupta* and *Graptolithus priodon*) and *Encrinites* (*Actinocrinus pulcher*), sometimes in rings and fragments and sometimes with the heads attached to long stems.

CHAPTER XXXIII.

Causes that produced the Physical Structure of the Vale of Clwyd, and History of the Clwyd and its Tributaries.

The physical structure of the Vale of Clwyd and the hilly country on either side of it will be easily understood by recurring to fig. 113. The subject as a piece of physical geology is of considerable interest, and may be briefly stated as follows:—

About six miles south of Ruthin the hill of Cricor-mawr overlooks the whole of the valley. From the carn on the top, about 1,150 feet above the sea, on a clear day the eye ranges more than

* Through Radnorshire to Builth, over a large area, the Wenlock Shales are about 1,500 feet thick, and often full of calcareous concretions, while from 2,000 to 3,000 feet of sandy strata lie between them and the Old Red Sandstone.

20 miles from some of the minor sources of the Clwyd to its outflow into the sea at Rhyl. No scene in Wales is more lovely of its kind than the fertile plains of the Vale of Clwyd. Overlooked on one side by the long Silurian range of Moel Fammau and on the other by the limestone slopes and cliffs of Denbigh and Abergele, the drift-covered and fertile lowland, gradually increasing in width, forms a marked contrast to the wildness of the hills amid which it lies, while far in the distance the plain merges into the low alluvial meadows that skirt the shores of Rhyl.

The valley in general is so deeply covered by glacial drift, that the Carboniferous and New Red Sandstone strata are rarely seen in place; but it is probable that the latter entirely belongs to that lowest member of the Bunter Sandstone, which in Cheshire and the central counties has been mapped by the Survey under the name of the Lower Soft Red or Mottled Sandstone. There is no other part of England or Wales where the Mesozoic rocks lie so enclosed as if in a long bay in the heart of the Palæozoic formations, and it is this that gives a charm so peculiar to the scenery of this remarkable valley.

The strata of the hills of the Wenlock series on either side, taken as a whole, may be resolved into a broad synclinal curve with minor subsidiary undulations. The eastern side of the great bend, as far as Upper Silurian rocks are concerned, is formed of the long range of hills of which Moel Fammau forms the culminating point about 1,823 feet in height, while the western side stretches from the neighbourhood of Conway to Carn Brys near Pentre Voelas, from whence bending to the east it runs to Garw Fynydd near Derwen, six miles westerly of the upper end of the Vale of Clwyd. Beyond this a continuation of the synclinal basin runs in a narrow strip far south-westerly to Tarannon in Montgomeryshire, near Llanbrynmair.

On Moel Fammau and the adjacent hills of the range the Silurian strata dip westerly at angles of about 30°. On the western side of the vale, for some miles in among the hills, the same western and south-western dips occur with many minor undulations, and though it is impossible to prove the point, it seems probable that these dips are continued deep under ground below the Vale of Clwyd in the Upper Silurian beds that form a base on which the Carboniferous strata rest unconformably, and which in their turn are unconformably overlaid by the New Red Sandstone. If this be so, the approximate centre of the synclinal bend *of the Wenlock rocks* lies about midway between the Vale of Clwyd and the western boundary of the Upper Silurian rocks between Garw Fynydd and the Vale of Conway.

All geologists acquainted with the structure of the country are well aware that the Carboniferous Limestone, with occasional narrow tracts of Upper Old Red Sandstone, lies quite unconformably on the Silurian strata. In places this unconformity may be seen, and where not seen, it may be easily inferred by the adverse strikes and dips in close proximity on the borders of the two formations where faults there are none. If any doubt

remained on this subject it is at once settled by the behaviour of the limestone all the way from the Severn at Llan-y-mynech to Diserth near Rhyddlan in the Vale of Clwyd, or in another range from the south end of the valley to Great Ormes Head near Conway; for in that long sweep of territory the limestone rests sometimes on beds very low in the Bala series of the Berwyn Hills, and further north on the higher Bala beds of Cyrn-y-Brain, still further north on Upper Silurian strata, while at Great Ormes Head, it is quite possible that the black slates beneath the limestone reached in the old mine shafts may belong to a geological horizon as low as the Llandeilo or Bala beds.

As we know that over great part of Wales and the adjoining counties the Lower Silurian rocks were disturbed, contorted, and much denuded before the deposition of the Upper Silurian strata began, so the extreme unconformity of the Carboniferous on the Wenlock rocks of Denbighshire and Flintshire, proves that the latter formation was disturbed and more or less thrown into undulating folds before the deposition of the Carboniferous Limestone. It is also clearly proved on mapping the formations, that the Upper Silurian strata had remained so long exposed above the sea, that they had already suffered a vast amount of waste and subærial denudation in pre-Carboniferous times.

Deep underneath the New Red Sandstone of the Vale of Clwyd, there can be little doubt that the Carboniferous rocks rest on the denuded edges of the Wenlock strata. This eroded surface lies considerably to the east of the general synclinal axis of the Upper Silurian region of Denbighshire previously mentioned. When the Old Red Sandstones that here and there in bands crop from underneath the limestone were deposited, I think it probable that they were spread out in the water of a lake, or of small lakes or lagoons, and when submergence took place at a later date the limestone began to be formed, and probably overspread vast tracts of Silurian formations far to the west and south, as witnessed by the still existing outlier of limestone near Corwen.

After the deposition of the Carboniferous Limestone and Coal-measures another disturbance took place, which had the effect of throwing these strata in the area under review into long anticlinal and synclinal curves. It does not follow, however, that before this disturbance the Carboniferous rocks of this area lay at the same relative height to the sea-level that they do now. On the contrary, in the Vale of Clwyd they seem to have been thrown lower than they were before by this synclinal bend, and higher elsewhere by the anticlinal curve. I have also no doubt that both Limestone and Coal-measures at one time spread far to the westward beyond the Vale in the manner indicated in the description of the Valley of the Dee (chap. 34), and therefore that the area since changed into the Vale of Clwyd was once covered by coal-bearing strata.

If, however, the Coal-measures were at one time present in the area of the Vale of Clwyd, it by no means follows that coal-bearing strata should now be found beneath the New Red

Sandstone, for it seems to me most probable that they were in great part removed by denudation from that area before the deposition of the New Red Sandstone began. There are several considerations bearing on this point, and as it has not only a scientific but also an economic bearing on the geology of the district I shall briefly state them.

In the first place, the Permian strata as a general rule lie unconformably on all the more ancient formations, resting as they do in various parts of England indifferently on Lower and Upper Silurian rocks, Old Red Sandstone, Millstone Grit, and Coal-measures, and it is worthy of remark that on the east of the Denbighshire coal-field they do not at the surface extend more than a mile north of Gresford, where they are overlapped by the New Red Sandstone, while as I believe (p. 302), there are no symptoms of Permian beds anywhere within the bounds of the Vale of Clwyd.

Our Permian strata, in my opinion, having been deposited *in inland, continental, salt or sometimes brackish lakes,* there is good reason for the belief that the Vale of Clwyd, like the adjoining areas, at that time stood well above the level of the sea, and was thus exposed to all the influences of sub-ærial denudation.

In the next place an inspection of the map shows, that before the deposition of the New Red Sandstone, the Carboniferous strata above the limestone, and even a portion of the latter, had been removed by denudation.

This denudation, therefore, must have taken place during the Permian epoch, that is to say, between the disturbance of the Carboniferous strata and the commencement of the deposition of the New Red Sandstone, a time so long, that much of the specially characteristic life of Palæozoic times dwindled and almost disappeared. We may thus infer, that the time was sufficient for the removal of the greater part of the Coal-measures from above the limestone by sub-ærial denudation over the area of what is now the Vale of Clwyd.

After that a change in the physical geography of the area admitted of the beginning of the deposition of those strata called New Red Sandstone, in a lake * in the interior of a partly remodelled continent, and thus it happens that I believe it to be probable that underneath that sandstone, in the whole of the Vale of Clwyd south of St. Asaph there is little chance of profitable Coal-measures being found.

Neither in my opinion is there much chance of Coal-measures being worked at a profit in the area lying between Prestatyn, Rhyddlan, Abergele and the sea coast, even though they exist beneath the thick overlying strata of New Red Sandstone. On the downthrow side of the great fault which forms the western boundary of the Carboniferous Limestone at Diserth, shale con-

* *See* "Physical Relations of the New Red Marl Rhætic Beds and Lower Lias," Geological Journal, 1871; and the Physical Geology and Geography of Great Britain, Chap. 11, and p. 308. A. C. Ramsay.

taining a thin bed of coal, and dipping north-west, has been found in the workings of the Talargoch lead mine, and the same beds, dipping north, have been found near Meliden. The dip of the strata in both places would lead to the assumption that higher and more profitable Coal-measures might be met with in a north-westerly and northerly direction before reaching the sea. In anticipation of this being the case a bore-hole was made at Foryd near Rhyl. The following details were given to Mr. Strahan of the Geological Survey by Mr. Leigh Howell of Bagillt, and they throw considerable light on the subject.

STRATIFICATION of the FORYD BORE HOLE, 1860.

		Yds.	ft.	in.
Clay	Post glacial.	0	2	0
Sand		6	1	0
Gravel		1	1	0
Mud and clay		5	1	6
Turf		0	0	6
Blue clay		3	1	4
Turf		0	1	6
Blue clay	Glacial.	0	1	0
Gravel		1	0	6
Red clay		3	0	8
Red Sand		0	1	0
Dark Sand		2	0	0
Red Sand		0	1	0
Sand and gravel		2	1	6
Red clay		2	2	6
Sand		1	1	0
Clay and gravel		0	2	0
Red sandstone	New Red Sandstone.	31	0	0
Metal (shale)		0	0	6
Red sandstone		0	1	0
Red metal (shale)		0	2	0
Red sandstone		11	0	10
Red shale		1	0	0
Red sandstone		3	1	10
Red metal (shale)		0	0	6
Rock		0	2	0
Red metal (shale)		0	1	6
Red sandstone		1	2	6
White Sandstone with black shades		0	1	2
Red sandstone		29	2	8
Red metal (shale)		0	0	8
Red sandstone		82	0	0
White and red rock		2	1	10
Red marl	Probably Carboniferous.	2	2	0
White rock		0	2	0
Red shale		15	0	1
Red shale rock		27	2	8
White hard rock		1	0	6
Red shale rock		2	1	2
		248	2	5

If we now endeavour to sum up the geological history of the Vale of Clwyd it would appear to be somewhat as follows:—

The Upper Silurian rocks that bound it and stretch far beyond its margins on both sides were thrown into anticlinal and synclinal

curves and much denuded before the deposition of the Carboniferous rocks, which therefore lie very unconformably upon them.

At the close of Carboniferous times, the strata of that epoch were in their turn (with all below them) disturbed, so that the Carboniferous Limestone, Millstone Grit, and Coal-measures of the area were thrown into broad anticlinal and synclinal folds, one of which formed the base of an old valley, the position of which coincided with what is now the Vale of Clwyd.

In such a situation the Carboniferous rocks were naturally preserved from the denudation which was laying bare the more elevated Silurian hills which now surround the valley.

The result was that a river, fed by tributary streams from the hills on the east, west, and south flowed down this valley, and by their means and other sub-aërial agencies during the Permian epoch, the greater part of the Upper Carboniferous strata of that old valley were eroded and cleared out, and only a portion of the Carboniferous series was left. An ancient escarpment of the limestone on the western side of the valley had already been *breached* during that process of denudation by some of the tributary streams that flowed from the old Silurian table land beyond.

I have said that these denudations to a great extent took place in Permian times, the Permian rocks apparently having never been deposited within the area of what is now the Vale of Clwyd, and that a river, a Permian or pre-Permian Clwyd, flowed down that old valley, which, like the present Clwyd, must have been fed by tributary streams that descended from the high grounds on all sides of the valley. But whereas, from the range of Moel Fammau the brooks were generally short, from the slopes on the opposite side of the valley many of the streams were much longer and of larger volume. This old system of drainage coming from the west has been continued more or less from that time to the present day in spite of occasional submergence. The streams first began to flow over a broad table-land or inclined plane gently sloping to the north and north-east across the surface of the Upper Silurian rocks, the highest part of that plain being miles to the west and south-west, in the high grounds that now overlook the Vale of the Conwy and Cerrig-y-Druidion. In this way, much modified by the influence of time, it happens that the chief drainage of the region now runs through a perfect network of valleys, and in earlier times the brooks gradually uniting to form larger streams, the rivers flowed in places across the old unscarped summit of the Limestone, and gradually deepening their channels cut gorges through it, one of the most marked of which is that of the Elwy.

Enumerated in order from north tc south, the first as they now flow is the Dulas, a stream about 12 miles in length, which cuts across the limestone escarpment from south to north in a deep valley, and enters the sea about two miles west of Abergele. The next of importance is the river Elwy, a large tributary of the Clwyd, formed by the union of the Cledw and the Aled, which themselves are fed by many affluents. The Elwy rises on the

ridge of hills that overlook Pentre Voelas from the north, and the length of its main channel is about 30 miles. For a space in a well marked valley it traverses the limestone a little across the line of strike, and suddenly bending at a right angle, passes into the region of the Carboniferous Sandstone, draining with all its tributaries more than half the area of the river-worn plateau of Upper Silurian rocks that lies between the neighbourhood of Cerrig-y-Druidion, Conway, and the Vale of Clwyd. Next comes the Clywedog, and lastly the Clwyd itself, which, rising on the eastern slope of Craig-bron-Banog,* follows a strange and devious course, first east and then south, into the region of the Bala beds, where suddenly turning eastward it runs in a deep valley right through the unfaulted escarpment of the Denbighshire flags, a mile south-west of Derwen, and at length breaches the Carboniferous Limestone in a steep-sided valley near Llanfair-Dyffryn-Clwyd, two miles south of Ruthin.

Such fluviatile vagaries as these can, in my opinion, only be accounted for on the hypothesis already mentioned of an ancient post-Carboniferous table land sloping gently to the north-east in the minor undulations of which the waters first began to flow, and gradually scooped out their valleys, and thus the Clwyd is, in the upper part of its channel, like the other streams enumerated, of older date than the New Red Sandstone through which in part its lower course now flows from Ruthin to the sea.

If we now turn to the east side of the valley, it is noticeable that, excepting at Tremeirchion near the north end of the vale, and at Y-Graig-wyllt near Dyffryn Clwyd, the limestone presents no escarpments to the east comparable to those of the western side of the valley. I have already mentioned the appearance of the limestone at intervals in narrow strips often not exceeding twenty yards in breadth. These consist generally of the topmost beds only of the Carboniferous Limestone, for they are overlaid by the purple sandstones, which have been referred to the Millstone Grit, or Lower Coal-measures.

It will also be observed that the New Red Sandstone abuts upon Silurian rocks at intervals all along the eastern side of the valley, and that the boundary between the high Silurian land and the low ground is remarkably straight. This circumstance is of itself suggestive of a line of faulting rather than a natural boundary; that this is the case is confirmed by the behaviour of the rocks on either side of the line.

On the west side of the valley all the north and south faults are known to be of later date than the New Red Sandstone, which, in two places, is thrown down against Silurian strata, and elsewhere against the Old Red Sandstone and Carboniferous Limestone. The question therefore arises whether the great fault on the eastern side of the valley is also exclusively of later date than the deposition of the New Red Sandstone. All the evidence seems to indicate that it is so, and it is worthy of remark that the New Red

* 2½ miles north-east of Llanfihangel-Glyn-Myfyr.

strata are not known to exist east of the fault in any of the minor valleys. There can be no doubt that the Carboniferous strata once overspread the whole of the Silurian range of Moel Fammau, and after upheaval formed part of a great table-land which extended far to the west. The uniformity of this table-land was first broken by the bending of the strata into the anticlinal and synclinal folds already mentioned, and after the deposition of the Triassic beds in the area of the synclinal fold, the great faults of that region were produced, the most important of which is that which extends all along the eastern side of the Vale of Clwyd.

Before these dislocations occurred, the valley must have formed a deep bight or arm of a great inland Triassic lake of unknown extent, into which the ancient Elwy and Clwyd and other streams seem to have flowed from the neighbouring hills. Whether or not the New Red Marl succeeded the sandstone in the Vale of Clwyd may be uncertain, but, considering its constant occurrence in the neighbouring county of Cheshire, it seems likely that it did so.

All this leaves an element of uncertainty as to the time when the *modern Clwyd* began to flow from south to north along the length of the valley now partly occupied by New Red Sandstone. It may possibly have begun in later mesozoic times, when our land formed part of a great continent, during the deposition of the freshwater and estuarine sediments of the Purbeck and Wealden series, or it may have begun still earlier, in Jurassic times, when Wales formed one of the islands of the Jurassic sea. However this may have been, I think it can scarcely be placed later than the Eocene Epoch, which witnessed another great estuary, and at which epoch we may be certain that all our present British mountain territories formed land even higher than at present, for since that time they must have suffered much from sub-aërial degradation. Even that supposition carries us a long way back into geological time, but this river, like others, did not flow without interruption, for during a late part of the Glacial Epoch a great submergence took place, when the Vale of the Clwyd and much of Britain was overflowed for a time by the sea, and those boulder beds and clays were deposited, full of ice-scratched stones and marine shells, so well seen in the clayey cliffs of the Elwy above St. Asaph. On the re-emergence of the land the river resumed its ancient direction down the valley, though not precisely in its ancient channel, for so thickly are the glacial deposits spread that only here and there have they been cut through by the streams so as to expose the underlying rocks. This concludes, as far as I am able to make it out, the intricate and perhaps too speculative geological history of the Vale of Clwyd, and of the river itself, and all its tributary streams.

CHAPTER XXXIV.

The Physical History of the Dee, &c.*

The surface drainage of a country is necessarily intimately related to its geology, and though it would be out of place in a book such as this to describe minutely the physical origin of all the principal rivers of North Wales, yet, having given much attention to the subject generally, I think it well to select a typical example of another of a great class of Welsh rivers, and, as far as I can, to account for its origin and explain its subsequent history. With differences of detail, the kind of argument applicable to the Dee may also be applied to many and perhaps almost all of the rivers of Wales that flow across Palæozoic rocks of older date than the Permian strata.

The surface of Bala Lake is 600 feet above the level of the sea, and is bounded by hills on the north-west and south-east that, near the lake, have elevations of about 1,200 and 1,300 feet, and therefore rise to heights of 600 and 700 feet above its level, while at greater distances, but still not far off, they rise to heights of 1,800 and 1,900 feet. On the south-west there is a long gentle slope, which attains a height of about 800 feet above the sea at the watershed close by the road to Dolgelli, or 200 feet above the lake, beyond which the river Wnion drains the country in a south-westerly direction into the estuary of the Mawddach.

The lake is about 130 feet in depth, and at its north-eastern end the waters of the Dee, escaping from this basin, first traverse an alluvial tract nearly three miles in length, the detritus of which has been carried from the adjoining hills by rivers, the largest of which enters the Dee near Pont Treweryn, about half a mile below Bala. Other good-sized streams form tributaries of the Dee below this point, and have helped to distribute the materials of the alluvial plain, beyond which, for a space of about a mile, the hills close in upon the banks of the river between Glandwynant and Pont Llandderfel. Between this point and the neighbourhood of Corwen the river for more than six miles again wanders through broad alluvial flats, after which it flows in many curvatures, sometimes great loops, between the steep slopes of the vale of Llangollen, which form the high and often flat-topped hills of Wenlock Shale and slate that often, not far from the river, rise to 800 and 1,200 feet above its banks.

Leaving this part of the valley, the Dee, with an exceedingly tortuous course, cuts through the marked escarpment of the Carboniferous rocks of the Denbighshire coalfield east of Llangollen, and passing through a less elevated tract of Permian strata, emerges on the low undulating country of New Red Sandstone

* This chapter originally appeared in the Journal of the Geological Society, 1876, to which a few minor additions have been made.

south of Chester, and finally, by a winding channel, enters the large tidal estuary of the Dee.

Emerging from the Permian region at Erbistock, the country through which the Dee flows to Chester may still be called a valley, in so far that miles to the west there rises the long slope of Permian and Carboniferous strata, while the eastern boundary is formed of the escarpments of Keuper Sandstone of the Peckforton Hills and Delamere Forest. Eliminating the minor modern effect on the scenery produced by a shroud of glacial drift, with other geologists I do not doubt that, before the Glacial Epoch, the contours of this wide valley were much the same as now; or, in other words, that, like the valley of the Mersey and others on the west of England, it is pre-glacial. The broad features of the history of this part of the valley are sufficiently obvious, but from Erbistock to the source of the river in Bala Lake the case is different, and the physical history of that long and often steep-sided river valley has, as far as I know, not been analysed.

At Holt, about seven miles south of Chester, the river is about 100 feet above the level of the sea; near Erbistock, eight miles further south, where the valley enters the Permian strata, about 225 feet; in the Vale of Llangollen, four miles west of the town, about 475 feet; near Corwen about 500 feet; while the level of the lake where the river rises is only 600 feet above the sea. The fall, therefore, from Erbistock to Chester, where the river is tidal, is about 225 feet in a north and south distance of 15 miles as the crow flies, and from Bala Lake to Erbistock about 375 feet in a direct line nearly east and west, so that the average slope is nearly the same the whole way, or about 15 feet per mile, taking no account of the numerous minor curvatures of the river.

It is a well known fact that the main great contours of Wales and other British mountain regions were in a general way the same as now, before the beginning of the Glacial Epoch, and that all the glacial striations of the mountain region of North Wales correspond to the trend of the greater valleys. The chief effect of the glaciers was, therefore, to grind and smooth the rocks into *moutonnée* forms in the bottoms of the valleys and on the sides of the mountains, and in doing this more or less to deepen and widen these valleys, and here and there to scoop out those rock-bound lake basins so common in all old intensely glaciated regions, and of which Bala Lake is one. The proof is simple.

At present the outflow of the lake is through an alluvial flat, the western end of which helps to dam up the water. But this alluvium, as already shown, is the gift of the tributary rivers that here enter the Dee. In older times the lake was more than double its present length, for while a mile and a half of delta at its south-western end where the river Wnion enters marks its ancient extent in that direction, the sheet of water also once extended two miles and three quarters east of Bala over the area now occupied by alluvium, giving the older lake a curved form, before torrents and rivers from the north and south filled that space with detritus borne down valleys that penetrate far in

among the hills. The effect of this is, that the lake now is little more than three and a half miles long, while formerly it was eight miles in length.

Bala Lake being 600 feet above the sea and about 130 feet deep, its bottom is 470 feet above the sea-level, and probably its rock-bottom may be deeper still, for two large and three small streams enter the lake on either side as it now stands, in addition to the main rivers of Afon Llyn and Dwfrdwy, which have deposited the delta at its south-western end, and doubtless the bottom of the lake, by means of these rivers, may be covered with fine detrital matter of unknown thickness.

But, even assuming that the present depth of the lake represents its rocky bottom, the fall of the river is only a few feet in the whole of the alluvial tract at its eastern end. Beyond this alluvium the Dee enters a narrow valley with solid rocks down, or almost down, to its banks, where, in older times, the original outflow of Bala Lake was, and it may be considered as almost certain that that old point of outflow is a true rock-barrier. If, however, there should still be any doubt about the upper end of this gorge having formed the original rocky dam of Bala Lake, there remains other evidence on the question of its being a true rock-basin, for, about two miles further on towards Llandrillo, the rocky bottom of the river is from 500 to 510 feet above the sea, while the bottom of the lake is only 470 feet above that level, and even beyond this at the ferry, half way between Corwen and Llangollen, 14 miles in a straight line E.N.E. of the lake, the rocky bottom of the river is about 475 feet above the sea, or 5 feet above the bottom of Bala Lake. As there is, and never could have been any other possible outlet for the water of the lake than the channel of the Dee, it is quite certain that it lies in a rock-bound basin; and, indeed, it seems to me more than likely that the large alluvial flat more than six miles in length between Llandrillo and Corwen may conceal one or more lake-basins now filled with detritus, brought down to the hollow by the numerous streams, large and small, that over this space now form tributaries of the Dee.* Similar alluvial flats, once lake-basins, are common in many old glacier valleys in Switzerland, Cumberland, Scotland, and elsewhere.

The glaciers that did this work of erosion came chiefly from both sides of Aran Mowddwy, down Cwm Croes and the valley of Dwfrdwy, and these converging near where Llanuwchllyn now stands, and aided by other tributary ice-streams, scooped out the basin of Bala Lake, and went far beyond its ancient boundary, *in a valley older than the beginning of the Glacial Epoch*, like all the other great valleys of Wales.

Such being certainly the case with this upper part of the valley of the Dee, it is natural and indeed inevitable to suppose that the further continuation of the valley towards and beyond Llangollen

* All the heights mentioned above were determined by angular measurements with the theodolite, by the late Professor Jukes, Mr. Aveline, and others. They are therefore not to be depended on within a few feet, but any possible errors of this kind are too small to affect the general argument.

is also of pre-glacial origin, and this, in my opinion, seems to be strengthened by the erratic blocks and glacial striations mentioned by Mr. Mackintosh in a memoir on boulders and erratics in Denbighshire, even though the author seems doubtfully to attribute some of these striations to the action of floating ice.* If for the sake of argument we assume that this part of the valley (unlike the upper part) is not pre-glacial, then the mass of country through which it runs must have formed a dam to the drainage of the waters of the upper Dee, which would have had the effect, even if these waters were only raised 200 feet, of filling with a lake, an area ramifying in all directions among the hills in vast tracts of Merionethshire. Of this supposititious lake there is no sign whatever.

Beyond Erbistock, where the Dee leaves the hills, and all down the estuary, the valley is undoubtedly pre-glacial, in so far that the country is largely shrouded by glacial drifts.

The question thus arises, by what means was the valley of the Dee excavated, and if it be possible to discover during what geological epoch did that excavation begin?

The valley in some respects may be compared to that of the Moselle, the physical character of which I have elsewhere indicated,† for, especially east of Corwen, between banks of Wenlock shale or slate that form a high and much erroded table-land, the Dee winds in many a curve, two of which about two miles above Llangollen form great loops, closely resembling the well-known loops of the Moselle above Alf. In both rivers a steep rocky high bank is apt to be opposed to the concave curve of the stream, while on the opposite or convex side the ground generally rises from the river with a long and gentle slope. This form of ground is characteristic of many rivers that flow through deep valleys in rainy countries, the elevated ground of which on either side is more or less flat-topped, and it invariably indicates a long-continued course of fluviatile erosion, begun at first by a wandering river on a high and slightly undulating table-land or plain.

The Silurian rocks of the region now called North Wales had undergone great disturbance and erosion, both atmospheric and marine, before and during the time that the deposition of the Carboniferous Limestone began, one result of this being that as the country was in great part slowly submerged, the limestone series was laid in a very unconformable manner on the denuded edges both of the Lower and Upper Silurian strata.

The high escarpment of Carboniferous Limestone in Denbighshire facing west, clearly shows that this limestone once extended a great deal further in that direction across much of the Lower Silurian rocks of the Berwyn Hills, and the Wenlock slates and shales that form the high land on either side of the valley of the Dee. This fact, if it needed confirmation, is still further proved by the well-known outlier of Carboniferous Limestone that lies

* In the 30th vol. of the Journal of the Geological Society, 1874.
† Physical Geology and Geography of Great Britain, Chapter 15.

far in among the hills in the valley of the Dee, two miles west of Corwen, ten miles distant from the nearest point of the escarpment, and six miles from the limestone at the southern end of the vale of Clwyd. This little patch, which occupies an area of something less than three quarters of a square mile, lies quite unconformably on the Wenlock shale on its south-western side, while on the south-east and north-east it is, as it were, dovetailed into the Silurian strata by two faults, and as its thickness, according to the late Professor Jukes may be about 2,000 feet, it is clear that the Carboniferous Limestone *in force*, once spread well across this and the neighbouring region.

Furthermore, everywhere to the east in Denbighshire and Flintshire, the limestone is overlaid by the Millstone Grit and Coal-measures, and I have no doubt that these upper Carboniferous strata at one time also spread far to the westward above the limestone across those parts of the Silurian strata now under review, but how far it would be difficult or perhaps impossible to determine. I feel certain, however, that what is now the high mountain region of Snowdonia, was at that time very different from its present form, and was never, *except on its low western outskirts*, covered by Carboniferous strata.

The statement that so much of Wales was once buried beneath Carboniferous rocks is at first sight somewhat startling, involving as it does such large revolutions in the physical geography of the district in early times.

First. An immense amount of denudation undergone by the Silurian rocks before the deposition of the Upper Old Red Sandstone (which sparingly exists in North Wales) and also of the Carboniferous Limestone.*

Secondly. It appears to me that this waste was accompanied by a gradual depression of the old land, so that in the long run, what many years ago I termed "a plain of marine denudation" was produced, similar to that well-known high plain of Carboniferous Limestone and Old Red Sandstone of the Mendip Hills on which the Liassic and Oolitic strata lie unconformably. In like manner the Carboniferous Limestone, overlaid by Millstone grit and Coal-measures, covered in flat-lying strata, the much older Silurian plain of marine denudation.

Thirdly. By succeeding changes of physical geography, after the deposition of the Millstone grit, the region was converted into part of one of those vast deltas, or at all events into broad swamps, undergoing slow intermittent depressions, during which the Coal-measures with all their successive terrestrial growths were formed.

Fourthly. The region was again disturbed and elevated, before and during the deposition of the Permian strata, which, taken on

* This amount could be approximately estimated by any one who would take the pains to restore the pre-Carboniferous anticlinal curves of the Silurian strata, but the doing of this in detail is not essential to my present argument. For the method, *see* Memoir "On the Denudation of South Wales, &c.," vol. 1, Memoirs of the Geological Survey, 1846.

a large scale, generally lie unconformably on the Coal-measures, and are in my opinion true inland continental deposits. Then by slow degrees, under sub-aërial agencies, a vast amount of the Carboniferous rocks were removed from above the Silurian formations, and the old plain of marine denudation was again, to a great extent, exposed, not less high but probably even more elevated than it is now, lying, as it then did, in the midst of a broad continental area.

This plain, or rather its relics, is of much wider extent than that part of it with which I am now concerned, and which lies on either side of the valley of the Dee, for beyond that area it extends far and wide into the northern part of Denbighshire, and also into Montgomeryshire and South Wales. Standing on the summit of Cader Idris or of Aran Mowddwy, 2,960 feet high, and looking east and south, the eye as far as it can reach ranges across a vast extent of old table-land, the plane surface of which near the Arans is about 1,900 feet above the level of the sea, or more than 1,000 feet below the summits of these neighbouring mountains. All intersected by unnumbered valleys, to the ordinary observer it is merely a hilly country, while an eye versed in physical geology at once recognises that all the diversities of feature are chiefly due to fluviatile erosions that have scooped out the valleys. I have for long looked upon this part of the table-land as probably also of pre-Carboniferous age, for reasons too long to be enumerated here.

This brings me to the main object of this Chapter, the origin and geological date of the valley of the Dee.

The country having been upheaved after the deposition of the Carboniferous strata, and a large part of these strata having been removed by denudation, the valley of the Dee did not then exist, or was only in a very rudimentary stage on the top of a wide slightly undulating table-land, having a gentle slope towards the east. It was then that first the Permian rocks were deposited, and afterwards the New Red Sandstone and Marle, and it may be recollected that, at all events in my opinion, both sets of these formations were deposited in inland salt lakes or seas. During these epochs, therefore, I hold that the old table-land lay high above the level of the sea, probably even higher than it does now, and that it formed part of a wide continental area.

After the Trias come the Jurassic formations, deposited around groups of islands in shallow seas, the effect of partial submergence of an older land, and themselves, in the middle and north of England, partly of fluviatile origin, the result of minor oscillations of level. Then followed the long fluviatile conditions under which the Purbeck and Wealden beds were deposited, during which epoch, the greater part of what is now Britain must have remained as part of a much larger land. After this come the Cretaceous formations, the lower half of which in the British area were certainly deposited near shore, while in later times, during the deposition of the chalk, there is no proof that the higher parts of Wales were altogether submerged, but rather the opposite. Later

still come the Eocene deposits, some of them of freshwater origin, and which in a large sense may be considered as estuarine, even including the London Clay, which seems to have been formed at the mouth of a great river, such as the Amazon or the Ganges. Our Miocene rocks are unmistakeably of terrestrial and freshwater origin, and the different members of the Crag were mere shallow sea or shore deposits.

It thus appears that since the beginning of the Permian epoch, the higher ground of Wales has formed land well raised above the level of the sea, and even if there be some doubt about this while the chalk was being deposited, that must have formed merely an episode when compared with the whole of the terrestrial period indicated above.

During that long lapse of geological ages, there was therefore ample time for the action of all the ordinary processes of sub-aërial denudation, the most powerful of which is the action of rain, rivers, and glaciers.

In the most elevated parts of North Wales the height of the highest mountains as they now stand between Cader Idris and Aran Mowddwy and Snowdonia, varies from about 2,920 to 3,571 feet. During the time of submergence, when the ground further east was buried under Carboniferous strata, the western mountain region stood well above the level of the sea, and higher relatively to the plain of marine denudation than it does now, for long before the Carboniferous epoch, and ever since that time it has suffered from unceasing sub-aërial degradation, and long lost hills and valleys must have prevailed in that old land, the shape of which it is now vain to speculate about.

Outside of this region, after the partial removal of the Carboniferous rocks, there lay, as already said, a wide table-land extending far to the south and also to the east and north-west. In the latter district this table-land sloped gently north-easterly and easterly, so that judging by those elevated parts of it that still remain more or less entire, in a distance of about 30 miles between Aran Mowddwy and the highest part of the carboniferous escarpment not far north of the Dee, the slope fell in height about 700 or 800 feet, at an angle of about 14′, equal to about 23 feet in a mile.

When, by the drainage of this old land, the Dee began to flow in its earliest channel, induced by minor undulations of the ground, it is clear that its present source, Bala Lake, had no existence; for whereas the river at that time must have flowed on the surface of land not less high but rather somewhat higher than that on either side of the present valley near Corwen and Llangollen, now in places from 1,600 to 1,800 feet high, the surface of Bala Lake is only 600 feet above the level of the sea, while the neighbouring watershed between the lake and Dolgelli is only 200 feet higher. As the river could not flow up hill it is clear that in that early stage of its history the valley of the Dee about Bala must have been at least from 1,300 to 1,400 feet higher than it

is now, and consisted of a mass of Silurian rocks, great part of which has since been removed by denudation.

As that country, according to the view already stated, has been land ever since the Permian epoch, excepting, perhaps, during a partial submergence for one short episode during glacial times, it seems to me that this waste of rocks was essentially produced by watery erosion, aided in a much less degree at a late epoch by glacier ice, and thus it happened that the Dee, a river of very ancient date, wandering hither and thither, by degrees deepened its channel in the same manner that the Rhine and the tortuous Moselle have cut out theirs, as I have described in a memoir "On the Physical History of the Valley of the Rhine." (Journal of the Geological Society, May 1874.)

For this reason it also happens that the Dee now cuts right through the Carboniferous escarpment west of Erbistock and the lower overlying area occupied by the Permian strata, just as the rivers of the Weald cut across the escarpments of the chalk; for when the Dee began to run, the carboniferous escarpment had no existence, and the strata of these formations stretched further to the west, ending along some line now unknown in a sort of feather edge, and forming part of the great inclined plane over which the Dee ran at a level, hundreds of feet above the bottom of its present valley. By and by, as the river channel deepened, the escarpment began to be formed, the face of which sloped in a direction at right angles to the general dip of the strata, after the habit of all such escarpments, by a process of recession which I have elsewhere explained. The whole was, in fact, strictly analogous to the manner in which the rivers of the Weald acted at a later date, first described in "The Physical Geology and Geography of Great Britain," and also for the same reason that the Thames now cuts across the escarpment of the chalk, as described in my memoir "On the River Courses of England and Wales."* Escaped into the low country of the new red series, the history of the Dee becomes simple and requires no special illustration.

But this process of ordinary fluviatile erosion is not the only agent that has been at work in Wales; for in late geological times the glacial epoch supervened and the moving ice of thick glaciers exercised a strong abrading power. Then it was that in the mountain region of the west so many lake-basins were scooped out, and among others the rock-bound basin of Bala Lake, and though the face of the country is always being slowly changed, the time that has elapsed since the Glacial Epoch closed is comparatively so short, that the large essential rocky features of the region traversed by the river have since that time undergone no important alteration.

I must now conclude with a few words about the length of geological time occupied in the excavation of the valley.

* Quarterly Journal of the Geological Society, May 1872.

It may be remembered by some readers, that in a paper on the excavation of the valley and gorge of the Rhine, I explained that the work of scooping it down to the present levels of the river, has been accomplished since the close of the Miocene epoch, and that the direction of the flow of its water then and now is connected with changes of physical geography, brought about by a great post-Miocene disturbance of the Alps.

The height of the old high-level terrace or old bed of the Rhine is about 400 feet above the present river, and the same is the case with its tributary the Moselle. The height of the relics of the old plain of marine denudation above the Dee, where it passes through the Wenlock strata is, to take a low estimate, not less than from 1,100 to 1,200 feet, and the time occupied in cutting that depth, extends from the Permian epoch down to the present day. The depth excavated in that period of time is not less than three times as great as that performed by the Rhine and Moselle, and I think no geologist will doubt that the time that elapsed between the Permian and Miocene epochs, was much more than three times the length of that which has elapsed since the beginning of Miocene times down to the present day. The Dee is but a petty stream when compared with even the smaller of the two German rivers, and it is obvious that the greater the body of water in a river, taken in connexion with the angle of its fall, the more powerful is its erosive force, and this may account for the much greater amount of time taken by our little river in the work of excavating its valley.

This great lapse of time also accounts for what I may call the ruinous state of the old table-land that lies on either side of the valley through which the Dee flows, for in the long geological ages that the region has remained as land, there has been ample time as the river gradually excavated its valley to lower levels for the drainage from the north and south to cut out tributary valleys, which, by watery erosion, got deeper and deeper in proportion to the gradual excavation of the main artery of the valley of the Dee, and thus it happens that what was once a long slightly undulating inclined plane has by degrees been converted into a hilly country simply by the power of rain and running water, aided in a minor degree for a time by glacier ice.

According to these views the sum of the whole matter is:—

First. That after the last important disturbance of the pre-Permian rocks, North Wales was carved by slow degrees and by sub-aërial agencies into its present mountainous form, chiefly between Permian times and the present day.

Second. That by far the greater part of that valley-excavating work was performed between Permian and pre-glacial times.

Third. That the work of the glaciers of the last glacial period somewhat deepened, widened, smoothed, and striated the minor outlines of the mountains and valleys, and excavated many rock-bound lake basins, but on a grand scale did not effect any great changes on the pre-existing larger contours of the country.

Fourth. That a minor submersion of part of Britain during part of the Glacial Epoch produced no important effects on the large outlines of the rocky scenery.

Fifth. That the effects of sub-aerial waste subsequent to the Glacial Epoch, have been comparatively small, simply for lack of time.

I may again remark that the method of analysis employed in this chapter is, I am convinced, applicable with variations to the reading of the history of all the more important rivers of Wales, Cumberland, and to much of Scotland.

Facts of a broad kind setting forth the general principles of watery erosion have been well known ever since the days of Hutton, though for long with a large class of geologists his views fell into undeserved neglect. The subject, indeed, with some definiteness is far older than Hutton for it was insisted upon by Ray; who, while the fourth edition of his Physico-Theological Discourses was passing through the press, was surprised and delighted to find that his opinion had been anticipated by "*Josephus Blancanus* in his book *De Mundi Profani*," in which he stated among other physical matters bearing on modern geology, that "our Appenine was at first one continued, even, eminent "ridge of land, not divided into particular mountains and hills by "intervening valleys as now it is, but that *after the rivers began* "*to flow down from the top of it*, by little and little fretting and "corroding the ground, they made valleys, and daily more and "more; and by this means the whole Appenine came to be "divided into many hills and mountains."

It is not, however, to insist on these simple principles, enlarged by modern research *versus* unnumbered unproved open faults, fractures, and tumultuous splittings of mountains, that this chapter has been prepared; but having already written on the physical history of rivers, both foreign and British, the details of which, comparatively simple, only grew on my mind by slow degrees, I at length fell on the Dee as an example of one of many rivers the history of which is much more complicated than, for example, that of the Po, the Rhine, the Severn, or the Thames, and I hope I have succeeded in unravelling that history. If so, the Dee, as a living river, has a history compared with which those of the Thames, the Rhine, the Ganges, and most of the great rivers of the modern world are matters of yesterday.

Llandovery or Pentamerus beds.—The evidence of the physical and palæontological relations of the Upper Llandovery beds to the underlying strata is as follows.

In North Wales, in Montgomeryshire and Merionethshire, the Lower Llandovery beds, being sometimes sandy, are separable lithologically from the slaty Bala beds beneath, but there is not only no direct evidence of unconformity between them, but as a rule there is a gradual lithological passage from the underlying to the overlying strata. In South Wales, near Llandovery,* there is some evidence at Noeth-Grug of a slight unconformity between them and the black slates, on which they lie in consequence of a gentle overlap. Indeed no one now considers the Lower Llandovery rocks in any other light than as an uppermost part of the Caradoc or Bala beds.

The Upper Llandovery rocks, however, behave in a very different manner. These range interruptedly from Marloes Bay in Pembrokeshire through Caermarthenshire to Builth; they also skirt the Longmynd, and the typical Silurian country of Shropshire; and everywhere they rest quite unconformably on older rocks, lying sometimes on the denuded edges of the Lower Llandovery beds, sometimes on Caradoc Sandstone, and at Builth and the Longmynd on the highly contorted and denuded strata which include the Bala and Llandeilo beds, and all the other lower Llandeilo, Arenig, and Cambrian strata.

There can be no doubt that from the top of the Caradoc or Bala beds downwards all the rocks were bent, contorted, and much denuded before the commencement of the deposition of the Upper Llandovery strata. It was the pressure incident to the contortion of these lower strata that induced that first cleavage characteristic of all the Cambrian and Lower Silurian rocks of Wales, in the highly disturbed regions north of the Towey in Caermarthenshire,† and west of the valley of Church Stretton in Shropshire. As we might expect, this cleavage is most intense in the lower slaty strata which, like those of Llanberis and Penrhyn, lie in the centre of the great anticlinal curves, for there the superincumbent weight and vertical pressure of the pile of overlying rock was necessarily greatest while lateral pressure was producing contortion and cleavage in the lower strata. At these great depths the component particles of the strata could not, by fracture and shattering, escape that intense force that compressed and turned them on their axes and thus produced cleavage. The great north-east faults of the region are all of later date than the contortion of the strata, while many of the smaller ones are clearly connected with it, and when the fractures took place, those parts of them that now intersect the surface of the country were deep under ground and unexposed by denudation.

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* Observed and mapped by Mr. Aveline.

† In Dynevor Park and its neighbourhood north of the Towey a small tract of country is uncleaved.

A later disturbance of the strata produced a second and more partial cleavage in the Upper Silurian rocks, so well marked at Llangollen and many other places, but at what precise period this occurred I am unable to say, though it must have been before the deposition of the Old Red Sandstone. In that case underneath a thick casing of unconformable Upper Silurian rocks, the Lower Silurian strata experienced a second great disturbance, evidence of which is occasionally found in a second set of cleavage planes in the lower Silurian rocks themselves, and also in the approximate identity of strike of Lower with Upper Silurian formations.

It is curious how rooted the idea is in some minds that the broad-spreading masses of igneous rocks in the Lower Silurian regions are connected with, and indeed the cause of, the disturbance of the strata amid which they lie; and some who are not far advanced in their geological studies, being told that there are volcanic rocks round Llyn Idwal above Nant-ffrancon, and Llyn Llydaw on Snowdon, at once jump to the conclusion that the sides of these and such like *cirques* or *corries* are the actual walls of Lower Silurian craters, in the hollows of which lakes lie, as in the extinct craters of the Eifel. In reality, such hollows are the result of denudation, and are intimately related to the icy phenomena of a very late period, and indeed in all glacier regions, past and present, high semi-circular hollows like these are exceedingly characteristic. So little, in fact, have the igneous rocks to do with the disturbance of the strata, that, as I have already said, they chiefly consist of lavas and ashes, belonging first to the Arenig and Llandeilo and secondly to the Bala period, and these old lavas and ashes have themselves suffered contortion and other accidents along with the strata among which they are interbedded. Even some of the great bosses of so-called intrusive porphyry sometimes seem only to be Cambrian and Lower Silurian rocks that have themselves been thoroughly altered by underground heat; and while occasionally these appear to have been somewhat affected by contortion, they have certainly been broken by the greater faults like the strata amid which they occur. Lying as they invariably do either amid the true volcanic rocks or in lower stratigraphical horizons, and being for the most part felspathic, some of them are doubtless the deep seated roots of volcanoes from whence the lavas and ashes came; and I do not see why this should not hold, even though they may in certain instances only have been Cambrian or Lower Silurian strata that passed into a state of fusion. The long lines of intrusive greenstone are more puzzling, and perhaps originated in the intrusion of matter into the Llandeilo and Bala beds from more deeply-seated melted matter, but as they are always associated with rocks on the volcanic horizons, they are certainly connected with the phenomena of the volcanoes, although they are lithologically different from the common lavas and ashes of the time.

Other greenstones, such as the narrow east and west dykes of Llanberis and the Penrhyn state quarries, are of later date, for a specimen from Penrhyn, shown me by the late Mr. Griffith Ellis,

contained a fragment of cleaved purple slate, and these dykes are therefore of later date than the contortions of the strata that produced the cleavage, and are probably post-carboniferous.

It would be an easy though a long task, to extend these descriptions still further, and to show how Lower Silurian and Cambrian strata crop out from under unconformable Upper Silurian beds in the areas of the Breidden Hills, and in the districts of Shelve and Builth, but though I constantly visited and assisted the officers of the Survey while the work was in progress, these regions rather lie outside the country with which personally I had most to do in mapping, and the more minute details of the districts are therefore less familiar to me. A glance at the map, however, shows that between Caernarvon Bay and Shropshire the lower strata rise to the surface four times in four great anticlinal curves: first at Llanberis, where the Cambrian rocks are the lowest that crop up; the second in Merionethshire, between Ffestiniog and Barmouth: the third in the boss of the Berwyn Hills, and the fourth in the heights of the Longmynd. In the synclinal hollows between the two last mentioned of these curves, Upper Silurian rocks have been partially saved from denudation, for I have no doubt that the greater part of them once spread across the Lower Silurian strata of large tracts of Wales where they are now absent.*

In that case it is probable that nearly the whole of Wales, before the Upper Silurian rocks were deposited, had suffered much denudation though not everywhere so extreme as that which took place in the Longmynd before the formation of the Upper Llandovery rocks, which, it is well known, in that region lie indifferently on Arenig beds, lowest Landeilo and uppermost Caradoc beds, and as may be seen in Mr. Aveline's sections across that country,† once covered the most elevated parts of the Cambrian and Lower Silurian rocks of the Longmynd. Whether much of the Lower Silurian rocks of Wales before that time partly formed plains of marine denudation worn into undulations I do not certainly know, but I think it probable that they did. However this may be, it seems certain that at much later periods great plains of marine denudation formed what is now the region of Wales, making table-lands, with intersecting valleys, one of which is the valley of the Dee. These table-lands were, I believe, older than the New Red Sandstone, but the details are too long to be discussed here.‡ By denudations, chiefly subaërial since that time, the details of the present outlines of Wales have been produced, modified by glacial action and probably by partial submersions, as, for example,

* As shown in Chapter XXXIV., I think it probable, after vast denudations of the older strata, that the Upper Carboniferous rocks themselves once covered a prodigiously greater part of that vast region than they do at present.

† Six-inch sections, sheet 34, line 2.

‡ The flat top of the Mendip hills, formed of denuded Carboniferous rocks and Old Red Sandstone, and unconformably overlaid by flat-lying Triassic strata formed a part of one of these plains; and the highly contorted Devonian strata of the Rhine and Moselle show like appearances. The phenomena are by no means isolated, but speak of a long period of comparative repose and subsequent tranquil elevation.

during the Cretaceous and part of the Glacial epoch. Under any circumstances there has been plenty of time for the cutting out of valleys in old table-lands by weather, running water, and glaciers, for I have no faith in the formation of any of these *existing systems of minor valleys* either by fractures or by unbroken curvatures of the strata. Great valleys between two distinct mountain ranges have often been formed in this way, minor ones rarely or almost never, and then under circumstances which I have only once seen in the Jura, and which do not exist anywhere in the British Islands. Indeed I cannot understand how anyone can reasonably explain the formation of the Welsh river-valleys by bending and fracture of beds, if he has once realised the idea of the thousands of feet of rocks that have been removed by denudation since the contortion of the strata took place.* When that contortion occurred and was finished, the mountain tops, for instance, of the Cader Idris and the Snowdon areas were still buried deep under many thousands of feet of higher Bala beds, and at a later period, I believe, at all events in part, by an immense thickness of Upper Silurian strata. During enormous geological periods that have since elapsed, these strata have been slowly removed by denudation and the present surface has been formed, the general result being that the harder rocks now stand out as rugged mountains, not because of extra rending and disturbance there, but because they have been and still are more difficult to wear away. Therefore, the valleys of the country, chiefly worn out by the drainage of these high lands and dating from times of inconceivable antiquity, are all of later date than the disturbances, and are now in no way immediately connected with them, whether there be faults in the hollows or not; for, like the present surface rocks, these faults themselves when formed, were (as far as regards the parts now at the surface) thousands of feet deep in the earth. Faults, however, *in conjunction with denudation*, often determine the direction of valleys first by bringing hard and soft rocks together, and also because faults are sometimes apt to produce lines of weakness on which all agents of denudation can work with additional power.

To the eye of one who appreciates the physical features of Wales there is indeed, on ascending one of the greater heights, nothing more striking than the average flatness of the tops of many of the hills, especially when the rocks which compose them are of tolerably uniform texture; a flatness, be it remembered, not connected with anything like a horizontal position in the beds, for everywhere they are contorted and often stand on end. All Wales shows this feature, from the Towey in Caermarthenshire to the slaty hills that flank Cader Idris and the Arans on the south and

* See an essay on this subject in the first volume of the Memoirs of the Geological Survey, "On the Denudation of South Wales and the Adjacent Counties," Ramsay. In that essay the main object was to show the vast amount of matter removed by denudation after the disturbance of the rocks. In that I believe I succeeded; but I am now aware that I attributed far too much to the power of the sea as having cut out many of the valleys of the country, and far too little to ordinary subaërial actions.

east, and even in the mountain land from Cader Idris to the Menai straits, traces of a similar approximate uniformity of height are plain to the experienced eye, showing the relics of an old form of ground, in which deep valleys have been not rent but scooped out. In lower ground, the features of Denbighshire west of the vale of Clwyd in a remarkable manner agree with these principles. There in an average table-land, the result of the quiet marine denudation of disturbed strata, innumerable valleys have been cut out of the solid mass, the accumulated drainage of which forms streams of tolerable size, now passing athwart the escarpment of Carboniferous limestone on their way to join the Clwyd. An instance still more striking is that which I have given in the physical history of the Dee, and by careful study of many geological details it would be easy to give others, explanatory of the origin of the present courses of the more important rivers of Wales.* Such principles, I am convinced, give, when well considered, the true key to the meaning of the present outlines of the country, and few subjects in physical geology would possess greater interest, than an exhaustive account of the denudations by which, *after* various disturbances of the strata, all Wales assumed its present form.

* For further information on this subject, see a paper "On the River-courses of England and Wales," Quart. Journ. of the Geological Society, 1872; and "The Physical Geology and Geography of Great Britain," both by the author of this Memoir.

APPENDIX.

ON THE FOSSILS OF NORTH WALES.

By J. W. SALTER, A.L.S., F.G.S., &c.,

LATE PALÆONTOLOGIST TO THE GEOLOGICAL SURVEY.

GREATLY ENLARGED AND PARTLY RE-ARRANGED

BY

ROBERT ETHERIDGE, F.R.S., F.G.S.,

PALÆONTOLOGIST TO THE GEOLOGICAL SURVEY,

1880.

LIST OF THE WOODCUTS.

Page.	Figure.	——	Localities.	Formation.
336	1	Filled up Annelide burrows	Bangor - -	Cambrian.
336	2	*Arenicolites*, double worm burrows.	Longmynd, &c. -	Cambrian.
345	3	Plaited surface of flaggy beds	Maentwrog - -	Lingula flags.
472	4	*Ischadites antiquus*, Salter -	Arenig - -	Upper Llandeilo.
486	5	*Hymenocaris? latus* - id. -	Tremadoc - -	Upper Tremadoc.
486	6	*Ceratiocaris? insperatus* id. -	Do. - -	Upper? Tremadoc.
491	7	*Agnostus*, sp. - - id. -	W. of Bala - -	Arenig.
512	8	*Psilocephalus inflatus* - id. -	Penmorfa - -	Lower Tremadoc.
518	9	*Ampyx tumidus* - - id. -	Bala - - -	Caradoc.
521	10	*Cheirurus Frederici* - id. -	Tremadoc - -	Upper Tremadoc.
538	11	*Lingulella lepis* - - id. -	Do. - -	Lower and Upper do.
547	12	*Modiolopsis pyrus* - id. -	N. Wales. -	Caradoc.
„		*Palæarca modiolaris* - id. -		
„		*P. quadrata* - - id. -		
„		*P. Billingsiana* - - id. -		
549	13	*Ctenodonta varicosa* - id. -	Do. - -	Do.
„		*Palæarca obscura* - id. -	Do. - -	Do.
„		*P.? bulla* - - - id. -	Wales and Shropshire.	Do.
553	14	*Holopea exserta*, Forbes -	Bala, N. Wales -	Do.
„		*H. conica* - - id. -	Do. - -	Do.
„		*H. lymnæoides* - id. -	Do. - -	Do.
„		*H. carinata* - id. -	Do. - -	Do.
„		*Cyclonema crebristria*, M'Coy	Do. - -	Do.
„		*Theca reversa*, Salter -	Wales and Shropshire.	Do.
555	15	*Bellerophon nodosus*, id. -	Do. - -	Do.
557	16	*B. perturbatus*, Sowerby -	Wales - -	Upper Llandeilo.
560	17	*Theca obtusa*, Salter -	N. Wales - -	Lingula flags.
561	18	*Pterotheca corrugata*, id. -	Do. - -	Caradoc.
562	19	*Conularia lævigata*, id. -	Do. - -	Do.

For Description of Plates, *see* end of volume.

APPENDIX.

PART I.

A DESCRIPTION of the fossils illustrative of the first Edition of the preceding memoir was undertaken by Mr. Salter, who on its completion felt that a more than ordinary apology was due if after all it should not be so full and satisfactory as may be desired.

Mr. Salter described and figured all the fossils of those obscure strata which occurred at the base of all then known.* They are fortunately partly within the North Welch area, and it has been thought worth while to include those observed in other districts, especially St. David's, S. Wales, so as to render the account more complete. But with respect to all the overlying strata, Llandeilo, Caradoc, Llandovery, Wenlock, &c., lists only are given, and the more prominent of the new species figured and described.† A very considerable number of less perfect or obscure forms still wait for another opportunity.

It would, indeed, be premature to attempt a complete catalogue of the organic remains of the principality. That can be better done when the geology of the southern districts and of Shropshire shall have been completed and described. And it is the less necessary to do this with the mass of the Welch fossils, since there is a very close affinity—nay, identity—between the organic remains throughout the whole region of Wales and those of Siluria proper. This will be abundantly proved by the catalogues and lists given in the sequel.

Even though the Caradoc rocks of Shropshire and those of Snowdon were for the most part deposited under very different conditions of the sea bed, the number of identical species is surprising. The argillaceous slates of Wales, the volcanic grits, the perpetual alternations of calcareous and felspathic beds with sandstone and shale, are conditions as unlike as possible to those of the continuously sandy deposits of Welchpool and Siluria; yet with few exceptions the fossils are identical. It is true the Caradoc rocks of neither of these regions were deposited under deep water conditions. And as the element of depth is found in modern seas to be of more importance than the condition of the sea bottom, it is not to be wondered at that there should be a great similarity between the two districts. The typical Caradoc is unquestionably a shallow-water deposit.

It is the same if we descend into the next formation, the Llandeilo rocks, for though, as explained by Prof. Ramsay, there is perfect conformity and a gradual stratigraphical passage in North Wales between these sub-formations, yet the Llandeilo rocks are clearly understood to be on the whole palæontologically distinct from and inferior to the Caradoc. The originally described limestones of Carmarthenshire and Radnorshire contain a peculiar series, which, differing as it does both in general aspect and specific characters from the fauna of the Bala region, is yet one and the same if the fauna of the various districts of Llandeilo age be compared one with the other.‡

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* In reference to the expression of Mr. Salter, "the fossils of those obscure strata which lie at the base of all," I beg to state that according to the classification of the Geological Survey adopted by Sir H. de la Beche and his associates in 1843 the strata thus alluded to are the Lingula flags of the Lower Silurian rocks. These strata have been rendered anything but *obscure*, particularly through the labours of Mr. Salter himself.
December 9, 1865. RODERICK I. MURCHISON.

† Mr. Salter, however, particularly endeavoured to illustrate those MSS. species mentioned in the Appendix to Siluria, 2d ed., so far as they relate to the Welch district.

‡ The distinctness and superposition of the Caradoc to the Llandeilo was never fully proved till the publication of the last edition of Siluria, the distinction having been in many cases rather a petrographical than a zoological one. But the whole of the Llandeilo and Caradoc strata of Wales having been examined by the Survey, and the Llandovery rocks clearly separated from both, the superposition of the Caradoc became manifest in the typical sections.

Of the "Arenig or Skiddaw group" of Sedgwick (the Lower Llandeilo of Murchison) much is now known. There is still some promise of extension in other parts of Wales not yet examined. There is close resemblance as has been partly shown by Sir Roderick Murchison in his Siluria,* between the fossils of the Stiper Stones, and those of the upper iron slates of Tremadoc, while the cliffs near St. David's Head have yielded a rich fauna of new species.

The "Tremadoc slate," now known in two districts, is so rich in conspicuous forms, that we have been able to separate it into two distinct zones; and each of these, thanks to the zeal and liberality of two gentlemen, have been pretty fully illustrated. To Messrs. Ash and Homfray of Portmadoc, the thanks of the Survey are due, both for independent and original work, and for their free communication of materials and help when Mr. Salter was engaged in tracing out the limits of this formation. Happily we do not need a name, for the "Tremadoc slates" were placed in their true position by Sedgwick in the account he gave of these rocks in 1847. The first actual section including them was the work of a geologist deeply buried in law books, but whose work has always been worth recording,—Mr. E. Davis, formerly of Presteign.† But Mr. Davis did not distinguish the group nor find a fossil. Professor Sedgwick found two, one of which was from the Tremadoc, and one from the Arenig rocks. The true relations of these beds are now cleared up. But their position, with respect to the Lingula flag below and the Arenig group above was clearly shown in 1851 by Sedgwick.‡

In the Lingula zone, including the Menevian below wherever it is seen, a perfect conformity is manifest. As it ranges round the great nucleus of North Wales (the Merionethshire anticlinal of Sedgwick) the characteristic Lingulæ and Trilobites are everywhere found. At St. David's in Pembrokeshire the same mollusca and crustacea are or can be detected, after a careful search, in their right places. And where this old formation shows itself in scanty outliers further eastward,§ the characteristic species are still present.

The characteristic fossils of the several formations are noticed in ascending order; these will give a basis for comparison of our own fauna with the published results of other labours. We have been able to do little more than roughly catalogue this large series, and render all the species accessible to all students. The Silurian fossils are arranged in their chief stratigraphical divisions, and in their natural history order, many however of the less perfect forms still remain under their generic titles only. Catalogues made during this labour include all the published and unpublished forms, and greatly extend the range of the known species. Only the published species are enumerated in this volume.—R.E.

Cambrian (Geol. Survey).

No fossils have yet been found in the grits and Sandstones of the mountain district between Harlech and Barmouth. And the numerous exposures of these rocks in the neighbourhood of the Bangor slate quarries yielded nothing, to a rather close search, except the very obscure fossils figured on page 336, Figs. 1, 2.

The only organic remains discovered in the true Cambrian rocks of Britain up to the year 1855 were the two species of *Oldhamia*, now well known in systematic works. They were regarded by their discoverer as more probably *Polyzoa* than *Hydrozoa*. Their alliance with the former group was strongly questioned by Mr. Busk, the most able authority on the subject,‖ *see also* p. 471.

Since these were found, Mr. Salter was fortunate enough to detect abundant traces of former life in the highly inclined strata of the Longmynd. A re-

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* 2d. ed., 1859, pp. 49-53, *ib.* 4th ed., pp. 47-53.

† *See* Quart. Geol. Journal, vol. 2, p. 70.

‡ Pal. Foss, Woodw. Mus. 1851, 1st fasciculus, advertisement.

§ At Pedwardine, near Brampton Bryan, Shropshire, and in the Malvern Hills. We have figured one or two of the Malvern trilobites in Pl. 5.

‖ In a letter to Mr. Salter, Mr. Busk says, "I can make little of them, except that there is an "absence of any characters by which they can be said to belong to the Polyzoa. . . . . I am "inclined to regard them as corallines, something perhaps after the type of *Acetabularia*, and "if, as the appearance of the cast seems to indicate, the rays of the frond were united by a "membrane or web, it would be much in favour of their being vegetable, and decisive against "their being Polyzoa."

ference to the Quarterly Geological Journal for August 1856 and January 1857, will show the character of these fossils, which are not repeated here, because they are fully figured in Part 2 of this memoir, pp. 246–251.

They consist chiefly of impressions, which were once evidently the burrows of marine annelides. Like those of the ordinary *Arenicolæ* of our coast, they had both entrance and exit holes, so that the hollows (*and the corresponding tubercles which are the casts of these on the lower surfaces of the beds*) are always in pairs. A reference to Woodcut 2 will explain this arrangement, which is very constant.

These hollows occur in such multitudes, and through so great an extent in the strata of the Longmynd (a full mile in vertical thickness), as to impress us with the belief that annelide life was very abundant in Cambrian times.

Immediately after Mr. Salter had found them, Dr. Kinahan searched vigorously the well exposed rocks of Bray head, and found even more conclusive evidence, which he published in the proceedings of the Geol. Soc. of Dublin for 1857 and 1858. He found the meandering burrows of the annelides themselves, the conical mound and its central aperture striated by the movements of the worm; in some cases the burrow was of a coiled form, in others vertical, or oblique, or horizontal, in the ancient "silt."

We refer to these fossil-prints beyond the district now described, because there can be no doubt that a like careful search in the finer strata of the Barmouth district would yield some or all of these markings. The fine-grained sandstone of Moel-y-ci near Bangor, here figured, is also well worth search, and an earnest and hopeful examination will often detect markings that escape us when we have reason to believe the field a barren one.

Foreign Cambrians.—Interesting discoveries have been made in Bohemia in this formation.

The ETAGE B. or Azoic rocks of Mr. Barrande had been as much neglected, as our own barren Cambrians were in former days. But Dr. Antonio Fritsch, keeper of the Geological and Fossil collections in the Royal Bohemian museum, Prague, has made special research for Cambrian fossils in this formation, and has been rewarded by discovering (1861), in thin slabs of sandstone, marks which can hardly be distinguished from our own Longmynd fossils. The same double burrows, the same vertical tubes on the edges of the slabs, testify to the existence of annelides in the fine sediment and mud of these most ancient sea shores.

That the long cylindrical and tortuous bodies found in the older rocks are not the remains of seaweeds is certain from their form and structure, since by no conceivable process could sand or sandy silt be made to *replace accurately* a soft cellular mass. Professor Forbes was disposed to refer many of them to *Alcyonarian* zoophytes; but this explanation was unnecessary, since we know of no remains of *Alcyonaria* in old rocks. Every requirement of the fossil is met by the supposition that we see the excreta of the annelide as it bored its way through silt and sand, carrying the material of one bed into that of the next, and threading them together into a tough and pasty mass.* The burrows are nearly always of a coarser texture and a lighter colour than the matrix. In Scandinavia the oldest fossiliferous rocks are the so-called Eophytal sandstone, the fucoid sandstone, and the Paradoxides schists, each group contains a peculiar fauna. Probably the Paradoxides beds may be the equivalent of our Menevian series. The Trilobita of these Scandinavian rocks are Paradoxides, Anopolenus conocorypha, Microdiscus, Arionellus, and Agnostus, with Lingulella, Obolella, and Protospongia. The Fucoid sandstones contain Cruzcana, and they occur earlier than in our lowest Lingula flags. Circumstances seem to show that the Swedish Cambrian rocks were deposited in a deeper sea than our British beds and further from land. Lingulella and Annelede burrows occur as in our Cambrian rocks.

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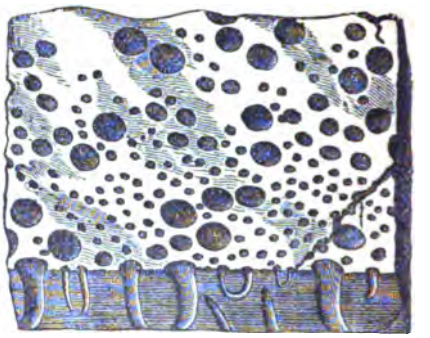
* The term "Fucoids" will have to be modified or all but expunged from our nomenclature. The well-known Fucoid bed of the Upper Ludlow rock is a tangled and matted mass of Annelide burrows. For a notice of the extensive part played by worms in the Palæozoic rocks, *see* Quart. Geol. Journ., vol. xiii., p. 205; also vol. xvi., p. 222. In some observations made a few years back on the sea coast of Pembrokeshire, Mr. Salter found that rocks much permeated by these burrows were tougher, and resisted the wear of the sea better than many others.

Fig. 1.

1. Filled up burrows of marine worms in Cambrian sandstone. Moel-y-ci, Bangor (*Chondrites*, Salter, Quart. Geol. Journ., vol. xii., p. 246.)

Fig. 2.



2. Surface of bed, with the double burrows of annelides. From the Stiper Stones, and other Silurian rocks. The surface also represents on a larger scale the marks on the strata in the Longmynd.

The list of true Cambrian fossils for Britain was very scanty up to the date of publication of the first edition of this memoir, but the researches over the St. David's area by Mr. Salter, Dr. Hicks, Mr. Homfray, the officers of the Survey, and others, have added so largely to the Cambrian fauna, that we are now enabled to add 15 species to the original list drawn up by Mr. Salter, and all from the red, grey, and purple grits and sandstones below the Menevian and Lower Lingula flags of St. David's. I enumerate or incorporate these in the following table, in which only 9 species were given in 1866 by Mr. Salter. The list of species in the first edition were reviewed in the Geological Magazine by Mr. Baily, of the Irish Geological Survey, and are here marked with an asterisk.*

Name and Reference.	Locality.
PROTOZOA.	
Protospongia major, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401. t. 16. f. 14–18.	Lower Cambrian and Menevian, St. David's.
HYDROZOA?	
**Oldhamia antiqua*, Forbes. Journal Geol. Soc. Dublin, 1848; Siluria, 2d. ed. p. 28, Fig. 2, Kinahan, Trans. Roy. Irish Acad., vol. 23, p. 557, Fig. 5.—var. *discreta* (*O. discreta*), ib. p. 556, Plate 26. f. 1–3.	Carrick McReilly mountain, Wicklow; Bray Head, Wicklow.
**O. radiata*, Forbes, ibid, 1848, Kinahan, l.c., p. 557, Figs. 3–5, 8–10. Plate 26. f. 4, 5.	Ditto, ditto.
**O.*—— sp.? Plate 26, f. 6, 7.	Ditto, ditto.
ANNELIDA.	
**Arenicolites didymus*, Salter. Quart. Geol. Journal, vol. xii., pl. 4. Fig. 1 (1856).	Longmynd, near Church Stretton.
**A. sparsus*, ibid. Quart. Geol. Journal, vol. xiii., pl. 5, Fig. 2.	Ditto, ditto.

* It is probable that the Hollybush Sandstones (olive and brownish green in colour) of the Malvern Hills and the Wrekin belong to this division of the Cambrian Rocks. They underlie the Black Shales of the Upper Lingula flags, and contain a peculiar series of fossils, *Scolites Scoleoderma* (*Trachyderma*), *antiquissima*, Salt., *Serpulites fistula* (Holl.). *Lingula squamosa* (Holl.), *Obolella Phillipsi* (Holl.) These sandstones are 600 feet thick, and contain at their base a conglomerate of rounded pebbles of quartz, felspar, &c., seen at the W. side of Ragged Stone Hill. *See* Holl. Quart. Journ. Geol. Soc., vol. xxi., pp. 87-89; *also* Callaway, *ib.*, vol. xxxiii., pp. 652-672.—R.E.

Name and Reference.	Locality.
**Histioderma hibernicum*, Kinahan. Journ. Geol. Soc. Dublin, 1858, pl. 6.	Bray Head, Wicklow.
**Haughtonia pœcila*, id. in the Nat. Hist. Review and Quart. Journ. Science, July 1859.	Ditto.
**Scolites* (vermicular burrows), Kinahan. Journ. Geol. Soc. Dublin, 1857, pl. 1., 1858, pl. 7; Salter, 1856, description and figure *supra*. Woodcut, f. 1.	Wicklow; Bangor; Longmynd.
CRUSTACEA.	
**Palæopyge Ramsayi*, Salter. Quart. Geol. Journ., vol. xii., 1856, pl. 4, Fig. 3. (? *Dikilocephalus.*)	Callow Hill, Longmynd.
Leperditia Cambrensis, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401, t. 15, f. 15–17.	Lower Cambrian, Longmynd group, St. David's.
L. Hicksii, Jones. Quart. Journ. Geol. Soc., vol. xxviii., p. 83, t. 5, f. 16, probably a larval trilobite.	Lower Cambrian, St. David's.
Agnostus Cambrensis, Hicks. Loc. cit., vol. xxvii., p. 400, t. 16, f. 11, 12.	Lower Cambrian, Nun's Well, St. David's.
Plutonia Sedgwickii, Hicks. Loc. cit., vol. xxvii. p. 399, t. 15, f. 1–8.	Ditto, ditto.
Paradoxides Harknessii, Hicks. Loc. cit., vol. xxvii, p. 399, t. 15, f. 9–11.	Ditto, ditto, and between Solva and Whitchurch.
P. Aurora, Salt. Loc. cit., vol. xxv., p. 54, t. 2, f. 9–12.	
P. Hicksii, Salt. Loc. cit., p. 55, t. 3, f. 1–10.	
Conocoryphe Lyellii, Hicks. Loc. cit., vol. xxvii., p. 399, t. 16, f. 1–7.	Lower Cambrian, Nun's Well, St. David's.
? *C. Bufo*, Hicks. Loc. cit., vol. xxv., p. 52, t. 2, f. 8.	
Microdiscus sculptus, Hicks. Loc. cit., vol. xxvii., p. 400, t. 16, f. 9–10.	Ditto, ditto.
MOLLUSCA.	
a. BRACHIOPODA.	
Lingulella primæva, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401, t. 15, f. 3–14.	Purple sandstones, Carefai, Nun's Hill, Porth Clais, St. David's.
L. ferruginæa, Salt. - - - -	Red Shales, St. David's.
b. PTEROPODA.	
Theca antiqua, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 400, t. 16, f. 13.	Longmynd, Harlech, and Menevian groups, St. David's.
T. penultima, Salt. Loc. cit., vol. xxviii., p. 180, t. 7, f. 15–16.	

MENEVIAN.

[Since the completion of the Appendix to the first edition in 1865, illustrating the palæontology of North Wales by Mr. J. W. Salter, F.G.S., &c., much new matter has been added to our knowledge relative to the occurrence and distribution of life through these oldest stratified rocks both of North and South Wales.

Additional research has resulted in finding Paradoxides, &c. near Dolgelly and on the same geological horizon as that at St. David's, South Wales, immediately above the Cambrian sandstones, in bands of uncleaved slates mixed with Trapean ashes. This, with other evidence, justified Hicks and Salter in regarding the Lower Lingula flags as a separate division or sub-group as distinguished from the Upper Lingula flags, as much so as the difference between the Upper Lingula flags and the overlying Tremadoc slates, for with few exceptions the *species* in all these groups are peculiar, with many distinct genera in each. To this group in 1865 Messrs. Hicks and Salter gave the name Menevian and established the horizon in the Promontory of St. David's, South Wales,* in the immediate vicinity of St. David's at Nun's Well; on the coast, the conglomerate and lowest Cambrian beds are well exposed, also the whole of the Lower Lingula flags and part of the Menevian and Lingula flags in true succession.

Portions of the Upper Grey series are assigned to the upper part of the true Lower Cambrian or "*Harlech Grit series.*" Annelida only have been found in the massive purple sandstones.

The well-known Porth-y-rhaw section in the Menevian and Lower Lingula flags is about 700 feet thick and more or less fossiliferous. It commences in the grey grit beds, passing upwards into grey flaggy and black bands.

Mr. Salter† in his note on the sections (loc. cit.) described by Mr. Hicks, notices and tabulates 33 species, and commenting on the vertical thickness and distribution of the fossils, proposed that the new name "Menevian"‡ should be given to the Lower Lingula flags of that area; as the Ffestiniog of Sedgwick was applied to the middle and upper groups of the Lingula flags in North Wales.

The Menevian beds, therefore, of St. David's Promontory and those of North Wales rest immediately upon the Harlech and Bangor series, passing imperceptibly into them below and into the true Lingula flags above. The classification then proposed by Mr. Salter was as follows:—

Upper Cambrian (Lingula flags)	Tremadoc group		(Upper and Lower).
	Ffestiniog	„ -	(Lingula flags).
	Menevian	„ -	(Lower Lingula flags).
Lower Cambrian - -	Harlech	„ -	(Grey grit and purple beds).
	Longmynd	„ -	(Sandstones and conglomerates).

An important table accompanies Mr. Salter's notes (loc. cit.) showing the species occurring in the Upper Grey series (or his Lower Cambrian) and the Black Slate series (base of his Upper Cambrian) or Lower Lingula flags. The fauna of the Menevian group is rich in crustacea (Trilobita), no less than 9 genera and 26 species occurring in it, also 6 Pteropoda, 2 Protozoa, and 1 Cystidian; most of these do not pass into the true and succeeding Lingula flags. 10 of the 26 Trilobita are common to the Menevians of South and North Wales, and 3 of the 9 genera are peculiar to St. David's, viz., Arionellus, Holocephalina, and Carausia. 3 of the same species of Agnostus occur in both areas; not so the Protozoa (Spongia). None are yet known in North Wales.

The largest Trilobites known, and with them the smallest (Agnostidæ), occur in these beds, abundantly so at St. David's. The great Paradoxides, Anopolenus, and Erinnys occur side by side with the minute forms of Agnostus and Microdiscus, and until the researches of Hicks and Salter through these lowest beds, the gigantic Olenidæ were not known.

In 1866, Mr. Plant, through Mr. E. Williamson,§ further added to the fauna of the Menevian and Lower Lingula flags at Tyddyngwladis and other localities near Dolgelly. In 1867, Messrs. Salter and Hicks noticed‖ the occurrence of a Lingulella in the Red Cambrian rocks (Menevian) south of

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* Brit. Asso. Report, 1865, p. 281, Birmingham.

† Further researches in the Lingula flags of S. Wales. Hicks and Salter. Brit. Asso. Report, 1865, p. 281.

‡ Menevian Group, N. and S. Wales; Sweden; Bohemia (Étage C. Barrande); Canada and N. America; and the St. John's group, Newfoundland.

§ Quart. Journ. Geol. Soc., vol. xxii., p. 505, and Trans. Manchester Geol. Soc., vol. v. p. 220, &c.

‖ Quart. Journ. Geol. Soc., vol. xxiii., p. 339.

Castell, St. David's, which same species characterises the Lowest Black flags of the Menevian group at Pen-y-pledian, St. David's. Additions were again made to the species contained in the Menevian beds of St. David's by the same authors in 1869, when new species of Trilobites were recognised and added to the already peculiar fauna species of the *Genus Conocoryphe, C. bufo,* and *Paradoxides; (P. Hicksii* and *P. aurora)* occur in the grey sandy series at the base of the Menevian group at Porth-y-rhaw, &c. Another valuable paper was communicated to the Geological Society by Messrs. Harkness and Hicks,* which dealt fully both with the geology and palæontology of the St. David's Promontory; the chief portion of the labour and research was due to Mr. Hicks, whose acquaintance with the area and knowledge of the fauna of the Cambrian and Silurian rocks enabled him to largely add to the palæontology of that remarkable district. The authors described the great series of red, purple, green, and grey rocks below the Grey Menevian beds, and which in their turn repose upon a conglomerate composed of quartz pebbles cemented in a purple or red arenaceous matrix about 60 feet thick, occurring on both sides of the so-called Pre-Cambrian ridge or axis; this old ridge they then believed to be of Laurentian age, or at any rate endeavoured to correlate it with the so-called Laurentian of other districts. That this quartziferous, crystalline, and unconformable mass underlies and is older than the whole series of the Lower Cambrian rocks of that area is certain, and as such is the key to the physical structure of the ancient headland of St. David's, the beds of this axis strike N.W. and S.E. Subsequent observation has shown that the overlying Cambrian rocks strike discordantly to the Pre-Cambrian ridge, or N.E. to S.W. The Cambrian rocks on both sides of the ridge contain organic remains older in time and different in species to any hitherto discovered in Britain or since the 1st edition of this memoir in 1865 was published,† when Mr. Salter described many and noticed all the species from the Lingula flags, Tremadoc, Arenig, and Llandeilo beds, of North Wales then known to the Geological Survey. Since that date, the St. David's area and much of North Wales has been carefully re-examined and described, much of it by Mr. Salter himself, and myself, and later still by Professor Ramsey. These researches have an important bearing upon the history and distribution of life through the Cambrian and Silurian series of North Wales, with which they must be correlated, although below the Menevian of St. David's; the Purple, Green, Red, and Grey sandstones yield a larger fauna, not yet known in Merionethshire, Carnarvonshire, or Montgomeryshire, or beneath the Menevian and Lingula flags of North Wales.

The lowest rocks in the St. David's Promontory yielding organic remains occur on both sides of the axis on the E. side of Ramsey Sound near Castell; they are red fissile shales overlying greenish flaggy sandstones and are about 50 feet in thickness, and on the S.E. side of the ridge at Porth Clais Harbour, Nun's Chappel, and Carefai are succeeded by about 100 feet of Purple and Greenish sandstones without fossils. Four species are known in the Red shales, viz., *Lingulella ferruginea, L. primœva, Leperditia cambrensis,* and a *Discina.* Fragments of a Trilobite occur but too imperfect to be determined.

The purple sandstones above mentioned which are conformable to the Red shales and 1,000 feet thick are not known to contain organic remains; succeeding these purple beds, however, are yellow or pale brown and grey sandstones about 150 feet thick, containing a fauna entirely new and characterised by the gigantic Trilobites, *Paradoxides Harknessi* and *Plutonia Sedgwickii,* with *Conocoryphe Lyellii, Agnostus Cambrensis,* and *Microdiscus punctatus,* and other remains. The headlands between Porth Clais harbour and Caerbrody are composed of these brown coloured sandstones which strike along the shore in a remarkable manner; the second headland E. of Porth Clais harbour has yielded most of the fossils. *Linguiella ferruginea,* var. *ovalis, Paradoxides Harknessi, Conocoryphe solvensis,* and other forms, are from the grey and purple flaggy sandstones and shales above the yellow Plutonia sandstones. These beds are extensively developed along the shore on the E. side of Ramsey sound (N.N.W. of the Axis).

* Quart. Journ. Geol. Soc., vol. xxvii., p. 384, "on the ancient rocks of St David's Promontory S. Wales, and their fossil contents."

† Mem. Geol. Surv., vol. iii., Geol. N. Wales, by Prof. A. C. Ramsey, LL.D., &c.

Until this fauna was discovered and worked out at St. David's, and subsequently more developed in N. Wales, the lowest sedimentary rocks of Britain were believed to be almost devoid of life, or "barren in fossils." Now, however, a remarkable fauna has rewarded the researches of many distinguished labourers in this field of research. Mr. Hicks has commented upon the peculiarity of, or peculiar feature in, the palæontology of these ancient rocks of St. David's,* referring to the occurrence of four distinct species of the genus *Paradoxides* in this Lower Cambrian rock, neither of the four species passing above the horizon of the Menevian, probably not into the Lower Lingula group of either area. Still more singular is the absence of the genus *Olenus* from the rocks of St. David's area, whereas they are abundant in N. Wales and Malvern, occurring both in the Lower and Upper Lingula flags.

Again comparison with the rocks and fauna in Europe and America of the same age as those of St. David's show resemblances so close as to appear identical as to age or time, and deposition. This is exemplified through the alum shales of Sweden as worked out by Angelin; the Primordial zone of Barrande as determined through its fossils, in which occur *Paradoxides, Conocoryphe, Ellipsocephalus, Agnostus,* and *Sao,* this last with us being absent in the St. David's Promontory; *Olenus* has not yet been detected in the Primordial rocks.

The *analogy,* if not generic *identity,* of this fauna with the Spanish "Primordial rocks" (though lithologically so very different from our British type) is very great. *Paradoxides, Arionellus, Conocoryphe* (*Conocephalites*), and *Agnostus* occurring as with us. Through America, Canada, and New Brunswick the same conditions prevail. In the latter Dr. Dawson notices *Conocoryphe* (14 species), *Paradoxides* (2 species), *Microdiscus* (1), and *Agnostus*† (2 species); thus, generically, the fauna is precisely our own.

Regarding the St. David's Menevians to be most typical both as to development and in abundance of organic remains (individually and specifically), it may be well, as done in the case of the true Cambrians, to add a list of those deemed truly Menevian, so called, for both areas (where they occur). The intricacy of the geological structure of the North Welch district renders both the mapping and the discovery of fossils in the Menevian beds far more difficult than in the St. David's Promontory, the strike being less disturbed in continuity, and I doubt not but an extensive fauna is yet to be obtained from the Menevian of N. Wales, where the typical Lower Lingula flags mantle round the still older Cambrian masses. The Menevian (Lower Lingula flags) of the Mawddach valley occur between the dark grey olive shales and the top of the purple sandstones and slates that form the Merionethshire dome and anticlinal, and are conformable to them, and have close structural affinity to beds of equivalent age near St. David's, not only are they physically the same, but many of the fossils are common to the two areas. The following species in one or both areas constitutes the chief portion of the Menevian fauna, or where they first appear, many being confined.‡—R.E.]

MENEVIAN SPECIES.

Name and reference.	South Wales.	North Wales.
Protospongia flabellata, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401, t. 16, f. 19.	St. David's.	—
P. major, Hicks. Ib., p. 401, t. 16, f. 14–18.	Ditto.	—
P. fenestrata, Salt. - - -	Ditto.	—
ECHINODERMATA.		
Protocystites Menevensis, Hicks. Ib., vol. xxviii., p. 180, t. 5, f. 19.	Ditto.	—

* Quart. Journ. Geol. Soc., vol. xxvii., p. 392.
† Acadian Geology, 2nd edition, p. 641.
‡ Many other species are given in the table on pp. 364–369.

Name and Reference.	South Wales.	North Wales.
CRUSTACEA.		
Agnostus Davidis, Salt. Quart. Journ. Geol. Soc., vol. xxviii., p. 174, t. 5, f. 2. 4.	Ditto -	Rhaidr-ddu Valley, Maentwrog, N. Wales.
A. Eskriggei, Hicks. Ib. 175, t. 5. f. 7.	Ditto -	Dolgelly.
A. scutalis, Salt. Quart. Journ. Geol. Soc., vol. xxviii., p. 175, t. 5, f. 9–14.	Ditto -	Maentwrog.
A. reticulatus, Ang. Pal. Succ. (*A. Nodosus*, Belt), Camb. Cat., p. 4.	- - -	Tyn-y-groes, Mawddach River (also Sweden).
A. Scarabæoides, Salt. Loc. cit., vol. xxviii., p. 175, t. 5, f. 8.	St. David's.	——
A. Barrandii, Salt. Loc. cit., p. 176, t. 5, f. 5, 6.	Ditto.	——
Paradoxides aurora, Salt. Loc. cit., vol. xxv., p. 54, t. 2, f. 9–12.	St. David's, Porth - y - Rhaw.	——
P. Hicksii, Salt. Loc. cit., p. 55, t. 3, f. 1–10 (is also Lower Cambrian.)	St. David's -	Camlan River, N. of Dolgelly. Robell-fawr.
P. Davidis, Salt. Loc. cit., vol. xix., p. 274, vol. xx.	Ditto -	Dolgelly, and near Robell-fawr.
Anopolenus Henrici, Salt. Loc. cit., vol. xx., p. 236, t. 13, f. 4, 5.	Ditto -	Rhaidr - ddu Valley, Tyddyngwladis, near Dolgelly.
A. impar, Hicks. Loc. cit., vol. xxviii., p. 179, t. 7, f. 1–7.	Ditto -	Maentwrog.
A. salteri, Hicks. Loc. cit., vol. xxi., p. 478.	Ditto.	——
Carausia Menevensis, Hicks. Loc. cit., vol. xxviii., p. 178, t. 6, f. 7.	Porth-y-Rhaw, St. David's.	——
Holocephalina inflata, Hicks. Loc. cit., vol. xxviii., p. 178, t. 6, f. 8–10.	St. David's.	——
H. primordialis, Salt. Loc. cit., vol. xx., p. 237, t. 13, f. 9.	Ditto.	——
Conocoryphe coronata, Barr. Syst. Sil., t. 13, f. 20. Ib., Hicks. Loc. cit., vol. xxviii., p. 178, t. 6, f. 11.	- - -	Waterfall Valley, Maentwrog.
C. applanata, Salt. Loc. cit., vol. xxv., p. 53, t. 2, f. 1, 2, 4, 5.	Porth-y-Rhaw, St. David's.	Maentwrog and Dolgelly.
C. humerosa, Salt. Loc. cit., vol. xxv., p. 54, t. 2, f. 7.	Ditto.	——
C. Bufo, Hicks. Loc. cit., vol. xxv., p. 52, t. 2, f. 8.	Ditto.	——
C. Solvensis. Loc. cit., vol. xxvii., p. 400, t. 16, f. 8.	Between Solva and Whitchurch, St. David's.	——
C. variolaris, Salt. Loc. cit., vol. xx., p. 236, t. 13, f. 6, 7.	Porth-y-Rhaw, St. David's.	——
C. Homfrayi, Salt. Loc. cit., vol. xxviii., p. 178, t. 6, f. 12.	- - -	Waterfall Valley, Maentwrog.
Erinrys venulosa, Salt. Loc. cit., vol. xxviii., p. 177, t. 6, f. 1–6.	- - -	Ditto, ditto.
Arionellus longicephalus, Hicks. Loc. cit., vol. xxviii., p. 176, t. 5, f. 20–26.	St. David's -	Maentwrog ?
Microdiscus punctatus, Salt. Loc. cit., vol. xx., p. 237, t. 13, f. 11.	Porth-y-Rhaw, St. David's.	——

Name and Reference.	South Wales.	North Wales.
PTEROPODA.		
Cyrtotheca hamula, Hicks. Loc. cit., vol. xxviii., p. 179, t. 7, f. 14.	St. David's.	Maentwrog.
Stenotheca cornucopia, Salt. Loc. cit., vol. xxviii., p. 180, t. 7, f. 12, 13.	Ditto.	—
Theca stiletto, Salt. Loc. cit., vol. xxviii., p. 180, t. 6, f. 18, 19.	Ditto.	—
Theca penultima, Salt. Loc. cit., vol. xxviii., p. 180, t. 7, f. 15, 16.	Ditto.	—
Theca corrugata, Salt. Loc. cit., vol. xx., p. 238, t. 13, f. 10.	Porth-y-Rhaw, St. David's.	—
Lingulella ferruginia, Salt. Loc. cit., vol. xxiii., p. 340.	St. David's.	—
Obolella maculata, Hicks. Brit. Asso. Rept., 1865, p. 285.	Ditto.	—
Orthis Hicksii, Salt. Geol. Mag., vol. v., p. 314, t. 16, f. 17–19.	Ditto.	—

R. E.

LINGULA FLAGS PROPER.

Above the Cambrian grits near Bangor, which contain the tracks of annelides mentioned in the last pages, dark coloured slates, with much iron forming the lower band of the Lingula flags (Menevian), have as yet proved barren of organic remains; while the thick sandstones which overlie them are rich in the characteristic Lingula (or Lingulella)* of the formation.

But in the corresponding beds of iron-stained slate, intercalated with sandstones, which wrap round the Merionethshire Cambrian rocks, there are abundant trilobites, chiefly of small size; and the more sandy strata that succeed (the equivalents, according to Professor Ramsay, of the Lingula sandstones or grits of the Bangor district) are rich in this peculiar shell, and moreover contain two or three perfect forms of crustacea of a primordial type (*Olenus micrurus*, and *Hymenocaris vermicauda*). These were described some time ago, in the decades of the Survey, and in a communication read by Mr. Salter before the British Association at Belfast so far back as 1852. They were found by the officers and collectors of the Survey, and have since been largely collected by Messrs. Ash and Homfray, of Portmadoc. *See plate* 2, p. 4, and 5, 6.

But the researches of Barrande, especially among the lower groups of the Silurian system in Bohemia, had meanwhile invested these few organisms with a double interest. In a visit paid to this country in 1851, for the express purpose of comparing his rich materials with our published and unpublished types, he recognised the "Lingula flag" of Sedgwick as the exact equivalent of his primordial stratum (*Étage* C.); and he has since, in many separate memoirs, successfully carried out this comparison, not only for Britain but for the European and American Continents.

To Barrande therefore belongs the whole credit of originating the term "primordial zone," and defining the fossil characteristics of this group of rocks which has grown in distinctness and geological importance day by day. Of its foreign equivalents a word or two only can be said further on.

His discovery was fully admitted, and adopted by the Survey, so soon as a re-examination of the typical district had been made. The evidence, as it stood in our catalogues, did not, at the time M. Barrande announced his belief, warrant us in coming to the conclusion that this zone was perfectly distinguishable by its organic remains. The fossil species had then scarcely been collected in Britain. The upper members of the formation (the most important), as will be seen from the fossil evidence, had not been recognised as distinct from the

* It has been found necessary to institute a new genus for this fossil. It partakes almost as much of the character of Obolus as it does of Lingula. Dr. S. Woodward first pointed out its chief character; it will be described in the sequel.

overlying formations of black slate, then supposed, and with great probability, to be inseparable from the ordinary Lower Silurian groups. And lastly, there then seemed to be no good reason for supposing the black slates of Malvern with Oleni to be so much older than the rocks which overlie them, though this point was essential to M. Barrande's supposition.*

As the small collections made during the progress of the Survey did not warrant the immediate application of M. de Barrande's views to the British Islands, and as certain anomalies presented themselves, (the few genera then obtained were not all of a primordial type,—see Brit. Assoc. Reports, 1852, p. 58,) Mr. Salter was directed by Sir H. De la Beche to re-examine a portion of the Lingula flag series, with special regard to the fossil succession, and found that the group was divisible into three distinct zones, two in the lower, and one in the upper division. The following is the ascending order :—

——	1853.	Fossils.
Lower Lingula flags.†	1. A lower series of black pyritous slates, with many beds of intercalated sandstone near the base. Maentwrog Waterfall, &c., &c.	*Agnostus princeps, Olenus cataractes, Lingulella Davisii.*
	2. A middle thick sandy series, the typical "Lingula flag" of Tremadoc, Ffestiniog, Dolgelly, &c. Carnedd-y-Filiast, Bangor.	*Olenus micrurus, Hymenocaris vermicauda, Lingulella Davisii* in great abundance, *Cruziana semiplicata.*
Upper Lingula flags.	3. An upper black slate, with hard pyritous bands, especiallly at the base, thickly crowded with fossils. Tremadoc, Maentwrog, and W. of Ffestiniog.	*Olenus alatus, O. scarabæoides, Agnostus princeps,* several sp. of *Conocoryphe, Orthis lenticularis, Dictyonema ? sociale.*
	(The species are figured on plates 1–5.)	
	These beds pass up into a series of dark shales with iron beds, the equivalent of the *base* of the great igneous series of Merionethshire; and in these occurred genera which might be compared with the Tremadoc and Arenig period. Pl. 6–10.	(The list of fossils has now been rendered more extensive, *see* pp. 348, 349, and the formation named "Tremadoc slates"), pp. 358, 359.

These fossil data, limited as they were by the scanty time at our disposal and the want of collectors, were sufficient to remove the difficulties felt before as to the *supposed* admixture of types respectively characteristic of the *primordial* and so-called *Llandeilo* faunas (Etages C. and D. of M. Barrande).

The new view was then at once adopted by the officers of the Survey, though from the complicated nature of the ground, and the doubt felt as to the utility of drawing fresh lines of demarcation, it was not thought advisable to give a distinct colour to the formation. The Primordial fauna was publicly recognised by Prof. Edw. Forbes, then palæontologist to the Survey, from the president's chair of the Geological Society (Anniversary Address, 1854, vol. 10, p. xxxi.). He there distinctly announced the division of this group into an upper and lower, as the result of the search made by Mr. Salter in 1853.‡ (Siluria, 2nd ed., p. 47.)

The appointment of Professor Forbes, in 1854, to the Edinburgh University chair, and the pressure of many duties prevented Mr. Salter doing much more than watch with interest the development of this important fauna in America and elsewhere. In 1860 Mr. Salter visited North Wales, as there were still

* *See* his Note "Sur l'Extension de Faune Prim.," Bull. Soc. Geol. Fr., 2nd ser., vol. xiv., 439.
† Probably part Menevian.
‡ In a recent memoir devoted to a review of the status of the primordial zone, M. Barrande suggests this division of the series for America, as it has also been indicated in Sweden by M. Angelin.

some points unsolved as to the passage of the group into the Tremadoc rocks above. Mr. Salter had, for part of the time, the hearty and eager assistance of Messrs. Homfray and Ash, the gentlemen above mentioned, and the services of our chief collector, Mr. R. Gibbs. Mr. Salter made out the succession and traced the three subdivisions westward to Criccieth* and eastward to Ffestiniog, and found abundant organic remains, especially in the upper subdivision.

This upper series (a black slate) rests somewhat abruptly on the lower and more sandy strata of the Lingula flagstones, but passes up insensibly into the Lower Tremadoc slate. It is almost impossible to draw a boundary line which shall define the upper margin of this black slate, which in its best development is only about 250 or 300 feet thick.

A line taken at that elevation above the Lingula Sandstones will be found to tally with a zone occupied by a peculiar net-like fossil, described on p. 535 as *Dictyonema sociale*. This abundant fossil marks an important boundary at the base of the overlying formations. As *Dictyonema sociale* is occasionally found in the black slates beneath this horizon, and never above it, while its nearest ally is a so-called primordial fossil in Sweden, it is included in these lists as the uppermost zone of the "Lingula flags," its position in the Black shales of Malvern is the same.

We may now therefore catalogue (with a few notes appended) the most important of the Lingula flag fossils, dividing them into an upper and a lower zone.†

Lower Lingula Flags.

[I. Black slate and sandstone with ash-beds, followed by (II.) a thick series of quartzose and ashy (Lingula) flags. *Foreign equivalent.*—Alum slates of Sweden and Norway.]

Name and Reference.	North Wales. Bangor, Tremadoc, and Dolgelly Districts.	South Wales, and other British Localities.	Foreign Localities.
Annelida.			
Scolites,‡ Worm burrows. Pl. 4, fig. 13; pl. 3, fig. 4.	Carnedd Ffiliast, S.E. of Bangor: S. of Maentwrog and Ffestiniog, on sandstones.	—	—
Helminthites,‡ Worm tracks	Do.	—	—
Scolecoderma §tuberculata, Salt. Pl. 5, fig. 24.	Borthwen, Tremadoc.	—	—
Cruziana semiplicata, Salter (1853). Pl. 3, f. 1–3.	Carnedd Ffiliast, Bangor; W. of Tremadoc; Maentwrog.	Beneath the Stiper stones (or an allied species) (1856).	—
Crustacea.			
Hymenocaris vermicauda, Salter (1852). Pl. 2, fig. 1–4, and tracks, Pl. 1.	Pentrefelen, W. of Penmorfa; Borth, S. of Portmadoc; Dolgelly, Carnarvon?	—	*A. pisiformis* (*princeps*) in Alum slates, Sweden.
Agnostus princeps, Salter. Pl. 5, fig. 1; Pl. 4, figs. 2, 11.	Maentwrog waterfall, and other places near Ffestiniog.	- - -	
Microdiscus punctatus, Salter, Quart. Geol. Journ., vol. xx., pl. 13, f. 11.	S. of Maentwrog - -	St. David's.	—
Olenus micrurus, Salter, Pl. 2, figs. 5, 6.	Marchllyn-Mawr, near Llanberis; Trawsfynydd; Dolgelly (at gold mines); Treflys; Borth; Tremadoc, &c.	—	—
Olenus cataractes, Salter. Pl. 5, fig. 23.	Maentwrog waterfall, Treflys, E. of Criccieth.	—	—
Paradoxides Hicksii (*Forchhammeri*), Salter. Pl. 4, fig. 12; *ib.*, Quart. Journ. Geol. Soc., vol. xxv., p. 55, pt. III., f. 1–10.	Locality, Dolgelly (probably Menevian).	St. David's -	Alum slates, Sweden?

* The best section showing in a small space the entire succession of the Lingula flags is that of Y-Graig-ddu, a promontory a few miles E. of Criccieth. A plaited, broken, and faulted arch of the black Lower Lingula beds, is there surmounted on either side and over its north end by a zone of hard Lingula flags, and these on their western side by the entire succession of the Upper Lingula flags, Tremadoc slate, &c.

† Descriptions of the species will be found with the plates further on, pp. 471–567.

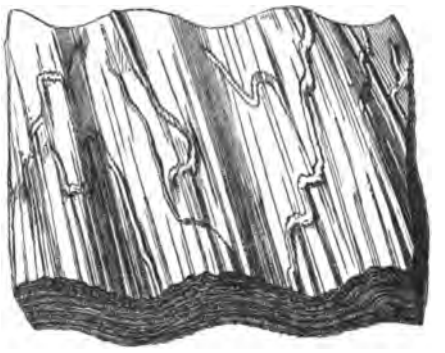
‡ Quart. Geol. Journal, vol. xiii., p. 205.

§ *See* Descriptions, p. 293.

Name and Reference.	North Wales. — Bangor, Tremadoc, and Dolgelly Districts.	South Wales, and other British Localities.	Foreign Localities.
Paradoxides Davidis, Salter, Quart. Geol. Journ., vol. xx., pl. 13, f. 1–3.	N. of Dolgelly (probably Menevian).	St. David's Head.	—
Holocephalina Primordialis, Salter, Quart. Geol. Journ., vol. xx., pl. 13, f. 9.	S. of Maentwrog - -	Porth Rhaw, St. David's.	—
Conocoryphe variolaris, Salter, Quart. Journ. Geol. Soc., vol. xx., p. 236, t. 13, f. 6, 7.	—	—	—
Primitia solvensis, Jones. Loc. cit., vol. xx., p. 238; *ib.*, A.M.N.H., 2nd ser., vol. xvii., p. 95, t. 7, f. 16.	—	—	—
Lingulella (*Lingula*) Davisii, M'Coy. Pl. 2, figs. 7-12.; pl. 4, fig. 14. (*L. ovata*, M'Coy, is said to be from Ffestiniog, probably this species is intended.)	Carnedd Filiast, Bangor; Marchllyn-Mawr, Llanberis; Tremadoc; Ffestiniog; Dolgelly; (everywhere in the middle band of the Lingula flags; rare in the lower black slates at Maentwrog).	Whitesand Bay, near St. David's Head, Pembrokeshire.	Alum slates Christiania? (Kjerulf).
Lingulella lepis, Salter. Woodcut 11, p. 334.	Borthwen? - - -	Abundant in the overlying Tremadoc slate.	—
Theca obtusa, Salter. Woodcut 17, p. 352.	Maentwrog waterfall and Tafarn Helig.	St. David's Head.	—
Theca penultima, Salter. Quart. Journ. Geol. Soc., vol. xxviii., p. 180, t. 7, f. 5–16.	—	—	—
Theca corrugata, Salter. Loc. cit., vol. xx., p. 238, t. 13, f. 10.	—	—	—

A few notes on the above list may be necessary. And first of the worm tracks and burrows. These ever-recurring markings are conspicuous in beds which otherwise show no traces of organic bodies. In the fine section of the Menevian and lowest Lingula flags, seen to advantage along the course of the Maentwrog river, all the lower beds of the formation, viz., thin beds of iron-stained sandstone and many of the slaty schists also, are permeated by them. These beds are often affected by an imperfect cleavage, which does not actually split them, but plaits the surfaces in a remarkable way, such as may be easily mistaken for organic remains. Over these large plaits the worm tracks are very conspicuous. When running with the plaits they are enlarged by them; when across they are broken up, something in the way indicated in the woodcut Fig. 3.

Fig. 3.



Plaited surface of a bed of *Lingula sandstone*, with Annelide tracks. S. of Maentwrog, river side (Lower Lingula flag).

* 13 other species are inserted in table pp. 364–369.

These surface markings may be properly called *Helminthites*, while the solid filled-up burrows, represented in Plate 3, and Plate 4, f. 13, are distinguished by the name of *Scolites*, terms which were proposed by Mr. Salter in 1857 as convenient definitions of very common phenomena. In the same way Mr. Salter added the term *Scolecoderma* for those conditions where the membranous or slimy tube of the worm itself is preserved, and this may easily be recognised, since in these cases the tube is always pressed flat. Such are common in many sandstone rocks, and need some recognition. But except in marked instances where surface ornament is preserved, it would be mischievous to give specific names.

For reasons given in the descriptions, *Cruziana* is probably the filled-up burrow of a marine annilide. Pl. 1 is believed to represent the tracks of the peculiar and very abundant phyllopod crustacean which Mr. Salter called *Hymenocaris* from its evidently very thin texture. These tracks are not uncommon on the sandy surfaces of the middle (or quartzose) bands of the Lingula flags. Especially are they abundant in the neighbourhood of Pentrefelen, or between that place and Wern on the Criccieth road. In a small quarry nearly opposite Wern Gate these tracks occur, and the same quarry is one of the best localities for the *Hymenocaris* itself. The fine specimen, from which we figure the caudal appendages, is from thence.

This locality is near the top of the Lingula flags, properly so called, and in the thin ripple-marked micaceous flags of this part of the series the greatest number of fossils occur. The beds are largely rippled, and in the ripple hollows, patches of drifted sand and broken Lingulæ occur, showing the action of the tidal or superficial currents on these old sandbanks, for such they certainly were. The annelide markings cross them in all directions, and the frequent sharp indentations are probably made by the tail-prongs of *Hymenocaris*, which help to keep up the idea of a shallow sandy bottom, thickly covered with living animals. The *Lingulella* is most abundant in these upper beds, in some localities so closely packed that you cannot lay a finger between the shells, but in others more scattered.

Trilobites are far from common in the Lingula flags itself; but in certain beds of the lower Lingula slates, which contain much iron, and some volcanic ash, the *Agnostus princeps* occurs in millions, together with an *Olenus*, of a species which Mr. Salter found to be distinct from any then described. At Pen-y-foel mountain, which overhangs the *Velyn Rhyd* fall, near Maentwrog, they are better seen than in any of the numerous neighbouring localities which yield them. Here the whole hill seems to be made up of pressed and altered iron slate, full of the distorted specimens of these little trilobites. Hardly a hand specimen but has many of them. We have represented a slab in its natural state in Pl. 4, f. 11, and a more perfect specimen is given by its side. There was some doubt if it were the same species which is so common in the alum slates of Sweden, it is now found to have distinct characters. Here, as there, the *Agnostus* is accompanied by a species of *Olenus*, a true primordial fossil.

As showing how rich this old fauna may be expected to prove, it may here be mentioned that the *Oleni* of the lower black slates, those of the Lingula flag itself, and those of the upper black slates, are all distinct. The place of the *Paradoxides Hicksii* is now known: it occurs a hundred feet or more above the base of the lower black slates, and has been detected both at Dolgelly and St. David's, in South Wales. (Quart. Geol. Journ., vol. xix., p. 275.)

Hymenocaris appears to be a far more plentiful fossil than at first supposed. It evidently affected sandy shallows rather than a deeper and muddy sea-bottom. In the fine slaty layers which form the capping of the Lower Lingula flags* it is most abundant, and generally in a good state of preservation. The coarser grits and sandstone of the Middle Lingula flags which form the high grounds west and south-west of Tremadoc have not yielded any specimens; but wherever the finer upper layers occur, both *Hymenocaris* and the *Lingulellæ* occur in plenty. In the cove of Borth, near Portmadoc, and at

* Grey slaty beds commence and terminate the series of Lingula flag sandstones; in several localities as a passage into or from the black slate beds. They are sparingly fossiliferous (chiefly containing *Oleni*) below the sandstones, but filled to repletion with *Lingulæ* at the top. The *Oleni* may be well seen in the grey slaty layers along the estuary at Aber-ia, opposite Port Madoc.

Wern, near Penmorfa, it is found entire. (Pl. 8, 2, f. 4.) Messrs. Ash and Homfray have perfect specimens.

The only shell, excepting *Discina* and *Lingulella*, which is known to occur in our N. Welsh Lower Lingula flags, is a large species of *Theca*. It is figured and described in p. 558. More perfect specimens have since occurred S. of Maentwrog.* The genus occurs on the same horizon in other countries. There are several Brachiopoda and other shells at St. David's, South Wales, viz., *Obolella sagittatis*, *O. maculata*, *Lingulella unguiculus*, *Theca penultima*, and *T. corrugata*.

The range and persistence of *Lingulella* is remarkable; it is found everywhere in quantity throughout the Tremadoc country, and the vale of *Ffestiniog*, and through the wild moory ground as far east as Llyn Dywarchen, where it was detected by Professor Ramsay; and found by Mr. Salter in plenty in 1853, and at Pont Nant-y-Lladron on the Bala road, also again in 1878 by Prof. Ramsay, Mr. Homfray, and Mr. Etheridge. East of that line the hard Lingula flags do not occur, but followed to the south-west and south it has been found by the surveyors everywhere to hold the same horizon, that is to say, in the middle or quartzose banded series of the Lingula flags. Mr. Salter found the *Lingulella* near the base, in company with trilobites, near the Maentwrog waterfall as above noticed, but it is small and ill-developed there, as it is also in the beds which overlie these Lingula strata. Yet, strange to say, it reappears in the upper portions of the next or overlying Tremadoc formation, of nearly its full size and character. This will be more specially noticed in speaking of the Tremadoc slates.

The distant locality of Whitesand Bay, St. David's, shows that the range of *Lingulella* southward is considerable. Its discovery there and inland by Mr. Aveline and Mr. Gibbs confirmed the conclusion already drawn on physical grounds that the whole succession of the lower beds might be traced in that headland; and later research by Mr. Salter, Mr. H. Hicks, and others, have largely added to the lists.

CHIEF LOCALITIES for LOWER LINGULA FLAG FOSSILS in NORTH WALES.

Borthwen	*Scolecoderma tuberculata*	Caernarvonshire.
	Lingulella lepis	
	L. Davisii	
W. of Tremadoc	*Cruziana semiplicata*	
Borth, W. of Tremadoc	*Hymenocaris vermicauda*	
	Olenus micrurus	
Treflys, E. of Criccieth	*Olenus micrurus*	
	O. cataractes	
Tremadoc	*Olenus micrurus*	
	Lingulella Davisii	
	Obolella sagittalis	
Pentrefelen, W. of Penmorfa	*Hymenocaris vermicauda*	
	Lingulella Davisii	
Carnedd-y-Filiast	*Scolites*	
	Cruziana semiplicata	
	Lingulella Davisii	
	Helminthites	
Bangor	*Cruziana semiplicata*	
	Lingulella Davisii	
Marchllyn-Maur, Llanberis	*Olenus micrurus*	Near Llanberis Lake, Caernarvonshire.
	Lingulella Davisii	
Maentwrog Waterfall	*Scolites*	
	Arionellus longicephalus?	
	Agnostus princeps	
	Microdiscus punctatus	
	Olenus cataractes	
	O. micrurus	
	Holocephalina	
	Lingulella Davisii	
	Theca obtusa	
	Cruziana semiplicata	

* Found associated with new Trilobites by Mr. D. Homfray.

Ffestiniog - -	*Scolites* - - -	Merionethshire.
	Olenus caractaci - -	
	Agnostus princeps - -	
	Lingulella Davisii - -	
	Hymenocaris vermicauda -	
Dolgelly - -	*Hymenocaris vermicauda* -	
	Olenus micrurus - -	
	Lingulella Davisii - -	
S. of Maentwrog -	*Microdiscus punctatus* -	
	Holocephalina - -	
Trawsfynydd -	*Olenus micrurus* - -	
Between Robbell-fawr and Traeth-Bach - -	*Lingulella Davisii* - -	
	Hymenocaris vermicauda -	
	Olenus micrurus - -	
	Agnostus princeps - -	
	Cruziana - - -	R.E.

Upper Lingula Flags.

Black shale, with pyritous bands.

So soon as we rise into the overlying black slates or Upper Lingula flags the fossils suddenly augment in number and variety. The following is the list, including the Malvern species :—

Name and Reference.	North Wales Districts. — Tremadoc Area.	South Wales, and other Districts.	Foreign Localities.
Annelide markings - -	Rare. S. of Maentwrog -	St. David's Head.	—
Scolecoderma antiquissima, Salt. (*Trachyderma*), Trans. Malvern Club, pt. 1.	- - - - - -	Malverns.	—
Serpulites fistula, Holl. - -	- - - - - -	Malverns.	—
Olenus alatus, Bœck, Pl. 4, fig. 3a.	Penmorfa Church, W. of Tremadoc; Carreg-wen, S. of Portmadoc.	- - -	Sweden, in alum slates.
(*O. bisulcatus*, Phill. Mem. Geo. Surv.; vol. ii., pt. 1, p. 55).	- - - - - -	Malverns, White-leaved Oak.	—
O. scarabæoides, Wahl. Pl. 4, figs. 1–5. (*O. spinulosus?* Phill. Mem. Geo. Surv., vol. ii., pt. 1, page 55).	Carreg-wen, S.W. of Portmadoc.	White-leaved Oak, Malvern hills.	Sweden, in alum slates.
O. flagellifer, Angelin? Pl. 5, figs. 8, 9.	Carreg-wen - -	- - -	Sweden, in alum slates.
Olenus, sp. — — Pl. 5, figs. 10, 11, 12	Carreg-wen.	—	—
O. serratus, Salt. Pl. 5, figs. 6, 7.	Carreg-wen - -	- - -	*O. spinulosus*, Sweden, is a close ally.
O. pauper, Phill. Geol., Oxford, p. 68, f. 4.	- - - - - -	Malverns.	—
O. Plantii, Salt., Camb. Cat., p. 11	Craig-y-Dinas, Moel Gron.	—	—
O. expansus, Salt. Camb. Cat., p. 12.	Moel Gron.	—	—
Olenus humilis, Phill. Mem. Geo. Surv., vol. 2. pt. 1, pl. 55.	- - - - - -	Malverns (*as above*).	—
Sphæropthalmus (*Olenus*) *pecten*, Salt., Phill. Geol., Oxford. Valley of the Thames.	- - - - - -	Do.	—
*Conocoryphe** (*Conocephalus*) *invita*, Salter, Siluria, 2nd ed., p. 47, foss. 7, pl. 4, figs. 5–7., pl. 7, fig. 5.	Penmorfa Church - -	- - -	[*C. Emmerichii*, *Barr.*, from Bohemia, is closely allied.]
Conocoryphe Malvernensis, Phill. Geol., Oxford, p. 68, f. 5.	- - - - - -	Malverns.	—
Conocoryphe abdita, Salt. Pl. 5, fig. 13.	Ogof-ddu, Criccieth.	—	—

* The reasons for adopting this name will be given in the description of the plates.

Name and Reference.	North Wales Districts. — Tremadoc Area.	South Wales, and other Districts.	Foreign Localities.
Conocoryphe depressa, Salter, Siluria, 4th ed., p. 46, foss. 8, f. 2.	Wern, Tremadoc.	—	—
Conocoryphe, sp., Pl. 5, figs. 14, 15	Ogof-ddu, Criccieth.	—	—
Conocoryphe, sp., ib., fig. 16	Ogof-ddu, Criccieth.	—	—
Conocoryphe?—sp., ib., fig. 17	Penmorfa Church.	—	—
Conocoryphe Williamsoni, Salt., Camb. Cat., p. 12.	Rhiwrfelyn upMawddach Pen-maen Pool; Dolgelly.	—	—
Dikelocephalus? (*Centropleura celticus*, Salt., or *Nemetus*). Pl. 5, figs. 21, 22.	Ogof-ddu, Criccieth	- - -	*Centropleura* . . . . *Angelin*, Sweden, closely allied.
D. ? ? discoidalis, Salt. Pl. 5, figs. 18, 19.	Ogof-ddu, Criccieth	- - -	*Dikelloc? planifrons*, Billings, Quebec, very nearly allied.
D. ? ? sp.———— Pl. 5., fig. 20.	Do.	- - -	Do. do.
Agnostus princeps, Salt. Pl. 4, figs. 2, 11; Pl. 5, fig. 1.	Penmorfa Church; Ogof-ddu, Criccieth; Carreg-wen, Borth; Portmadoc.	Malverns; St. David's (in the Tremadoc slate).	*A. exsculptus*, Ang., is closely allied, Alum slate, Sweden.
Agnostus M'Coyi, Salt., Mem. Geol. Surv., Dec. xi., t. 1, f. 6, 7	- - - - -	Malverns.	—
A. trisectus, Salt., Mem. Geol. Surv., Dec. xi., p. 10, t. 1, f. 11.	- - - - -	Do.	—
Dictyonema sociale, Salter. Pl. 4, fig. 1. (In uppermost layers only.)	Gelli-fwyog, S. of Ffestiniog Syemte, N.W. of Ffestiniog; Railroad above Plas Oakley; Borth wood, Portmadoc; W. side of Moel-y-gest.	Pedwardine, near Brampton Bryan. Malverns.	*D. flabelliformis*, Russia and Sweden; a close ally.
Kutorgina Cingulata, Bill.	- - - - -	Malverns.	—
Lingula squamosa, Holl.	- - - - -	Malverns.	—
Lingulella lepis, Salt. Woodcut, 11, p. 334.	Borth; Cefn-cyfarnedd; W. side of Moel-y-gest.	—	—
———— *Davisii*, M'Coy, Pl. 2, f. 7–12.	? Llyn Tryweryn; Pont Nant Lladron.	—	—
Orthis lenticularis, Dalm. Pl. 4, figs. 8, 9, 10.	Penmorfa Church; Ogof-ddu.	- - -	Sweden; abundant.
Obolella Salteri, Holl., Phill. Geol., Oxford, p. 68, f. 11.	- - - - -	Malverns.	—
Lingula Pygmæa, Salt., Quart. Journ. Geol. Soc., vol. xxi.	- - - - -	Malverns.	—

The Dictyonema occurs rather above the level of the black slate. But the last fossil *Orthis lenticularis* is found in the greatest profusion at the very base of these black slates, exactly where they repose upon the quartzose layers of the middle group filled with *Lingulellæ*. In the roadside brook, a few yards beyond Penmorfa Church, this *Orthis* was found in 1853; and again in 1860, many slabs of this gregarious species was obtained. As the bed lies just at the base of the wall, and a fault occurs close by, it may very easily be overlooked. A better locality is the cliff of Ogof-ddu, near Criccieth, where, on the west side of the jutting promontory of Craig-ddu a complete section (from the *Lingula* flags to the upper Tremadoc slates) may be obtained. Here, at the junction of the black slate with the Lingula flag, *Orthis lenticularis* occurs in myriads, the fossils standing out in bright orange colour (peroxide of iron) from the dark pyritous slate. This locality is one of the most easily worked and the most prolific of all the Upper Lingula flag localities. The above list will show that several of the forms have only yet been detected there—*Conocoryphe, Dikelocephalus, &c.* *Orthis lenticularis* and the *Agnostus princeps* occur there in millions.

A good fossil locality is to be found on the farm of Carreg-wen, half a mile west of the village of Borth. From this spot nearly all the species of *Olenus* were obtained, and large specimens of *Agnostus princeps*, which is our English representative of the very abundant *A. pisiformis* of Sweden. This again is one of the few points where a true section from the fossiliferous Lingula flag to the Tremadoc series can be traced, for east and west of it the ground is much faulted.

Although the upper black slate can be traced all round the outcrop of the true Lingula flags, fossils have only been detected in a few places; but this is only for want of searching, and more pleasant and profitable ground to work

we do not know in the British Islands. Mr. Callaway also finds in the Hollybush sandstones at the N.E. end of Little Caradoc two species the same as at Malvern, viz.: *Kutorgina cingulata*, Billings, and *Serpulites fistula*, Holl. These are also found on the flanks of the Wrekin in the same beds. Above the Hollybush sandstone he finds the Shineton shales (Harnage shales so called by him), and believes them to be probably of Tremadoc age.*

Above this formation lies a group of beds to which very little attention had been paid, but to which, in his careful Survey of N. Wales, Professor Sedgwick gave the name of Tremadoc Slate. He obtained but a single fossil from this upper member, nor could Mr. Salter and himself then estimate the full importance of this group, which overlies the Lidgula flag and distinctly passes under the Arenig and Llandeilo rocks both in N. and S. Wales.

CHIEF LOCALITIES for UPPER LINGULA FLAG FOSSILS in NORTH WALES.

Penmorfa Church, W. of Tremadoc	*Ellipsocephalus?*	Caernarvonshire.
	Olenus alatus	
	Conocoryphe invita	
	C. abdita	
	Agnostus princeps	
	Orthis lenticularis	
Wern, Tremadoc	*Conocoryphe depressa*	
Borth Wood	*Dictyonema sociale*	
Borth	*Lingulella lepis*	
	Agnostus princeps	
Carreg-wen, S.W. of Portmadoc	*Olenus alatus*	
	O. scarabæoides (spinulosus)	
	O. flagellifer	
	O. serratus	
	O., sp.	
	Agnostus princeps	
Ogof-ddu, Criccieth	*Conocoryphe abdita*	
	C., sp.	
	C., sp.	
	Dikelocephalus celticus (Centropleura)	
	D. discoidalis	
	D., sp.	
	Agnostus princeps	
	Orthis lenticularis	
Gelli-fwyog	*Dictyonema sociale.*	
S. of Maentwrog	*Annelide markings*	Merionethshire.
Ffestiniog Rail, above Plas Oakley	*Dictyonema sociale*	
Llyn Tryweryn	*Olenus serratus*	
	Obolella sagittatis	
	Lingulella Davisii	
S.W. of do., under Moel-llyfnant	*Orthis lenticularis*	
	Obolella	
Pont-nant Lladron	*Lingulella Davisii*	
Llyn-y-dywarchen	*Lingulella Davisii*	
Cefn Cyfarnedd	*Lingulella lepis.*	
Tremadoc	*Lingulella Davisii.*	

R.E.

TREMADOC ROCKS.

Little or nothing was known of the Tremadoc rocks in the St. David's Promontory when the first edition of the present Memoir was written by Professor Ramsay, and its appendix by Mr. Salter in 1865. It was well understood and

* *Vide* Quart Journ. Geol. Soc., vol. 33, pp. 660–663.

recognised, however, in North Wales. In 1866 Messrs. Salter and Hicks* drew up a list of all those fossils which had been discovered up to that time. It was not, however, until December 1872 (published in 1873), when Dr. Hicks described the Tremadoc fauna of the mainland at St. David's and that of Ramsey Island,† that we were quite aware of the palæontological relation existing between the typical North and South Welsh areas and their fossil remains. In his paper of 1872 Hicks completely confirmed the presence of the Tremadoc rocks previously recognised by Mr. Salter and himself in 1866 at Ramsey Island, where they conformably succeed the hard siliceous flaggy Lingula flags. They have little palæontological affinity with the overlying although conformable Arenig group, only 15 species out of 84 in the Tremadoc series being common to or connect the two formations. Careful analysis of the species both for North and South Wales show that the Tremadoc rocks of North Wales contain 42 species, 22 of which are Trilobita, with only 3 Brachiopoda; Pteropoda and Heteropoda 12; no Hydrozoa or Lamellibranchs known in the northern area. The South Welsh fauna at St. David's numbers 30 species, 7 only being Trilobita, and only illustrating 2 genera, *Nesuretus* and *Niobe*, the former having 4 species, *Niobe* 3; and there are only two species common to N. and S. Wales out of the whole known fauna, viz. *Lingulella Davisii* and *L. lepis*. It would thus appear that two distinct colonies existed in the Tremadoc Sea even at so short a distance, but we have now no trace of any barrier, did such exist which could have physically or geographically separated these two fauna. Fifteen species connect the Tremadoc with the Arenig, and 7 of these are N. Welsh species; amongst the Trilobota, *Asaphus Homfrayi* and *Ogygia scutatrix* (out of the 22) are the only two; *Lingulella Davisii*, *L. lepis*, and *Orthis lenticularis*, as we should expect, amongst the Brachiopoda, and *Conularia Homfrayi*, *Bellerophon multistriatus*, and *Orthoceras sericeum*; no Gasteropod has yet been found in the Tremadoc of either area. The Lingula flags below, containing 58 species, are connected by 18 species, which are common to the two groups.

The Tremadoc rocks occupy a considerable tract of country east of the city of St. David's, also at the N. end of Whitesand Bay, stretching N.E., and at the N.E. end of Ramsey Island, where they are nearly 1,000 feet thick, resting there upon the Lingula flags, and with the iron-stained Arenig slates resting on them. A rich fauna has been obtained through the researches of Messrs. Hicks, Homfray, Hopkinson, and others; 30 species (nearly, if not all, new) have been obtained. There is some little difficulty in comparing the Tremadoc rocks of N. with S. Wales; at St. David's they are so intimately connected, both on stratigraphical and lithological grounds, that the boundary line can scarcely or only be arbitrarily traced and fixed. Palæontologically they seem to be upon the same horizon as the Lower Tremadoc rocks of N. Wales. The South Wales or St. David's series appear to have been laid down or accumulated in a shallow sea, being rough and coarse-grained sandstones and flaggy beds, also characterised by the Annelida in the form of worm-tracks. The earliest or first known Lamellibranchiata in Britain occur in the Tremadoc rocks of Ramsey Island, no less than 5 genera and 12 species being found at the N.W. end of the island, 2 species of *Ctenodonta*, 2 species of *Palæarca*, 2 species of *Glyptarca*, 2 species of *Davidia*, and 4 species of *Modiolopsis*; these are associated with the earliest known *Crinoid Dendrocrinus cambrensis*, and the star fish *Palæasterina Ramseyensis*. The Brachiopoda are represented by 4 genera and 9 species;‡ no Lamellibranchs are known in either the Lower or Upper Tremadoc rocks of N. Wales, whereas we see that 12 species occur at St. David's. We also learn, through Dr. Hicks (loc. cit.), of the occurrence of a new genus of Trilobite, occurring in Ramsey Island, and also in the same beds at Tremanhire, E. of St. David's. This new genus Mr. Hicks has named "*Nesuretus*," and determines 4 species, *N. Ramseyensis*, *N. quadratus*, *N. recurvatus*, *N. elongatus*, and *var. obesus*. Associated with and in the same beds are two new species of *Niobe*, *N. Menapiensis* and *N. Solvensis*, species differing much from the typical form *N. Homfrayi* of N. Wales, and

* Brit. Assoc. Report, vol. for 1865.
† On the Tremadoc Rocks in the Neighbourhood of St. David's, South Wales, and their Fossil Contents by H. Hicks, Esq., F.G.S., Quart. Journ. Geol. Soc. vol. 29, p. 39, 1873.
‡ Hicks, loc. cit., p. 42 and note.

found only in the lowest beds. Mr. Hicks believes that the lower portion of the St. David's, Tremadoc rocks were contemporaneously deposited with the upper black slates of the Lingula flags of N. Wales; this may well be, looking at the difference in the fauna, only two species being common to the two areas, as well as the distance and perhaps difference in depth at the time of deposition. Again, the absence of the fine black slates in the Upper Lingula flags of St. David's, so characteristic of the N. Wales and Malvern beds, may be due to depth, shallow in one area, deep in the other. The Tremadoc series is divided into three groups by Mr. Hicks, the lowest, at St. David's, consisting of grey fissile or flaggy sandstones, exposed at Ramsey Island, Tremanhire and Llanviran, and characterised by a peculiar but well-defined fauna, and distinct from the Lingula flags below, 8 species only out of 84 in the Tremadoc coming up from the Lingula flags or are common to the two groups; they are *Agnostus princeps, Ampyx prænuncius, Conocoryphe depressa, Lingulella Davisii, L. lepis, Orthis lenticularis, Dictyonema sociale.* The middle and upper divisions occur in N. Wales.

The new genus *Nesuretus* (4 species), *Niobe Menapiensis* (Hicks), and *N. Solvensis* (Hicks), *Dendrocrinus, Palæasterina,* the first known Lamellibranchs *Davidia, Palæarca, Glyptarca,* and *Modiolopsis,* &c., essentially typify the lowest division of the Tremadoc series; none of these have yet been discovered in the Lower Tremadoc of North Wales, although the slates and flags are well exposed at the base of Moel-y-gest, Borthwood, Penmorfa, and Portmadoc, also east of the estuary at Aber-ia Castel, Deudraeth, near Maentwrog and Ffestiniog. In places Crustacea and Pteropoda are abundant, the Cephalopoda, represented for the first time by *Orthoceras sericeum* and *Cyrtoceras precox,* occur at the close of the Lower Tremadoc or in beds of passage between the Lower and Upper Tremadoc, at Llanerch, and pass to or are common to the upper series at Tuhwnt-y-bwlch and Garth. A species of *Orthoceras* has been found at St. David's in the Lower Tremadoc, but is not determined. The Lower Tremadoc of St. David's area may be estimated at 1,000 feet in thickness; in the cliffs at Ramsey Island they dip 60° S.E.; at Tremanhire the beds differ lithologically from those of Ramsey Island, being more arenaceous, and the slates are less cleaved; Paran, where the beds are little cleaved, has yielded the best specimens; the beds, however, are by far better exposed at the N.E. corner of Ramsey Island and made up of the characteristic fossils above named.* 42 species are now known in the Lower Tremadoc rocks of North and 30 in South Wales;† 37 of these are Trilobita, 3 Echinodermata, 11 Brachiopoda, 12 Lamellibranchs, 9 Pteropoda, and 4 Nucleobranchs; 28 species are peculiar to or confined, so far as we know, to this Lower Tremadoc series of the St. David's area, but only 3 species are common to the Tremadoc slates of North and South Wales, or the Portmadoc area, and that of St. David's, viz., Niobe Homfrayi, Lingulella Davisii, and L. lepis. As before stated, the Upper Tremadoc of St. David's appears to be upon the horizon of the lower part of the Arenig group, and have, palæontologically speaking, certain species in common with the Upper Tremadoc, such as *Cheirurus Frederici, Asaphus Homfrayi, A. affinis, Ogygia scutatrix,* and *Bellerophon multistriatus,* the former associated also in the Arenig rocks with a rich graptolithic fauna, which, without doubt, is upon the horizon or age of the Quebec group of Canada.‡ Mr. Hicks has suggested that the term Upper Tremadoc should be abandoned, or that the upper part of the Upper Tremadoc should be incorporated with the Lower Arenig. Doubtless the whole Arenig series is much more closely allied to the succeeding and overlying Llandeilo series than the underlying Tremadoc rocks as exhibited at St. David's. It is interesting and important to show this relationship of the Tremadoc to the Arenig, and the Arenig to the Llandeilo. The whole Tremadoc fauna consists of 84 species, the Arenig 149 (42 of which are Hydrozoa), and the Llandeilo proper 175, and 44 of these are Hydrozoa, yet nearly all distinct species.

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* Hicks, loc. cit., p. 44.

† 67 occur in both the Lower and Upper of both areas.

‡ Mr. Homfray states that some of the Graptolites were discovered by Mr. Ash in the Upper Tremadoc rocks of North Wales. In the St. David's area no Graptolites are known in the Tremadoc or below the Lower Arenig, in which 17 species occur, chiefly in Ramsey Island and Whitesand Bay. Mr. Homfray's views are supported by the fact that the Tremadoc is much thicker in North Wales than in South Wales, and the Arenig less.

The following tabular view gives the zoological values of the horizons:—

Groups.	Plants.	Amorph.	Hydrozoa.	Actinozoa.	Echinodermata.	Annelida.	Crustacea.	Polyzoa.	Brachiopoda.	Lamellibranchiata.	Gasteropoda.	Pteropoda.	Nucleobranchiata.	Cephalopoda.
Tremadoc - - -	—	—	2	—	2	tracks	31	—	11	12	—	10	4	2
Arenig - - -	—	—	42	—	—	11	49	—	19	8	4	8	6	5
Llandeilo - - -	—	1	44	6	3	10	47	—	32	6	12	3	7	8

The chief groups of value for comparison are the Hydrozoa, Crustacea, Brachiopoda, and Pteropoda.

It will be seen that there is only 2 species of Graptolite in the Tremadoc group in Britain, and none are truly known lower than the Arenig in any older horizon in Europe or America. They are of high value here as expressing a large generic and specific fauna in both the Arenig and Llandeilo series, 42 in one and 44 in the other, and yet only 3 species in common between the two formations. In other words, out of the 42 species in the Arenig group, 3 species only pass to the Llandeilo; they are *Didymograptus gibberulus*, *Climacograptus confertus*, and *C. bicornis*.

The change in the physical conditions at the close of the Tremadoc deposits and commencement of the Arenig was certainly favourable to the development of this one division of the Cœlenterata, enabling us to catalogue about 40 species, but which at its close either died out or became so changed or modified as to compel us to look upon the Llandeilo Rhabdophora as entirely new, 3 only of the 42 in the Arenig or in the 44 Llandeilo being common, and about 30 of the 44 Llandeilo forms pass to the Caradoc, which had a Graptolite fauna of 40 species (nearly one-half derived). The Rhabdophora have an important bearing upon the determination of this group of rocks and their stratigraphical value. The Crustacea are even more remarkable; the Tremadoc yields 18 genera and 37 species from the two areas (North and South Wales), and yet 5 genera only of the 18 are common to this and the Arenig, viz., *Asaphus*, *Cheirurus*, *Ogygia*, *Ampyx*, and *Agnostus;* and of the 37 species only 6 are common, viz., *Asaphus affinis*, *A. Homfrayi*, *Cheirurus Frederici*, *Ogygia scutatrix*, *O. Selwyni*, and *Dionide atra*, and which pass up or connect the two formations. The Phyllopoda, *Ceratiocaris* and *Lingulocaris* are strictly Tremadoc forms. The value of the palæontological change is still greater when we estimate the number of genera (17) and species (50) of the Crustacea in the whole of the Arenig rocks, 3 only of which pass to or connect the crustacean fauna with the Llandeilo proper, viz., *Trinucleus Ramsayi*, *T. Sedgwickii*, and *Homalonotus bisulcatus;* these will be discussed under the Arenig group, indeed, the palæontological break was almost complete at the close of both the Lingula flags, the Tremadoc, and Arenig.

An important addition has been made to the fauna of the Lower Tremadoc rocks through the researches of Mr. Callaway* over the Wrekin area. A group of shales termed by him the "Shineton Shales" are, I think, conclusively shown to be of Lower Tremadoc age, or passage beds between the Upper Lingula flags and the Tremadoc. He bases his evidence first, from the fossil remains in the shales, and secondly, from their "correlation with rocks in other localities;" all the species but two are new, and also four sub-genera. Mr. Callaway also concludes that the Shineton shales represent the Dictyonema shales of Malvern, which there, as at the Wrekin, overlie the Hollybush sandstone. Again, the three Shineton species, *Dictyonema sociale*, *Conophrys Salopiensis*, and *Platypeltis Croftii*, occur in the drab or light-coloured upper shales (Dictyonema shales) of Malvern. *Asaphus* (*Asaphellus*) *Homfrayi* is a common Trilobita at Shineton, and is the characteristic form everywhere in the

* Quart. Journ. Geol. Soc., vol. xxxiii., pp. 667-671.

Upper Tremadoc of West Wales, and passes into the succeeding Arenig beds.* Mr. Callaway has established two sub-genera from these shales—*Asaphellus* and *Platypeltis*, and two genera, *Conophrys* and *Lichapyge*, and a remarkable form of *Cystidean*, *Macrocystella*, possessing a slender crinoidal-like stem, and simple *calicular pinnulæ*. The species occurring in these shales are *Asaphus* (*Asaphellus*) *Homfrayi*, Salt.; *Asaphus* (*Platypeltis*) *Croftii*, Call.; *Conophrys Salopiensis*, Call.; *Lichapyge cuspidata*, Call.; *Conocoryphe monile*, Salt.; *Agnostus dux*, *Xenus Salteri*, Call.; *Olenus triarthrus*, Call.; *Theca lineata*, Call.; *Bellerophon Shinetonensis*, *Lingulella Nicholsoni*, Call.; *Obolella Sabrinæ*, Call.; *Macrocystella Maria*, Call.; *Dendrograptus*, and *Dictyonema sociale*, Salter.

The following table shows the fauna of the North and South Welsh and Shropshire Tremadoc rocks, and the 8 species common to the Lingula flags, also the 15 that pass to the Arenigs:—] R.E.

Lingula Flags.	Tremadoc Species.†	North Wales.	South Wales.‡	Shropshire (Shineton).	Pass to Arenig.
	Bryograptus Callavei, Lapw.			×	
	Dendrograptus, sp., Call.			×	
×	*Dictyonema sociale*, Salt.	×		×	
	Dendrocrinus Cambrensis, Hicks		×		
	Macrocystella mariæ, Call.			×	
	Palasterina Ramseyensis, Hicks		×		
	Agnostus Barlowi, Belt.	×			
×	*A. princeps*, Salt.	×			
	A. dux, Call.			×	
×	*Ampyx prænuntius*, Salt.	×			
	Calymene Blumenbachii, var.	×			
	Angelina Sedgwickii, Salt. and var.	×			
	Asaphus affinis, M'Coy	×			×
	A. Homfrayi (*asaphellus*), Salt.	×		×	×
	A. Croftii (*platypeltis*)			×	
	Ceratrocaris insperatus, Salt.	×			
	C. latus, Salt.	×			
	Cheirurus Frederici, Salt.	×			×
×	*Conocoryphe depressa*, Salt.	×			
	C. olenoides, Salt.	×			
	C. vexata, Salt.	×			
	C. versimilis, Salt.	×			
	C. monile, Salt.			×	
	Dikelocephalus furca, Salt.	×			
	D. discoidalis, Salt.	×			
	Dionide atra, Salt.	×			
	Lingulocaris lingulocomes, M'Coy	×			
	Conophrys Salopiensis, Call.			×	
	Nesuretus Ramseyensis, Hicks		×		
	N. recurvatus, Hicks		×		
	N. quadratus, Hicks		×		
	N. elongatus, Hicks and var.		×		
	Niobe Homfrayi, Salt.	×	×		
	N. menapiensis, Hicks		×		
	N. solvensis, Hicks		×		
	Ogygia peltata, Salt.	×			
	O. scutatrix, Salt.	×			×
	O. Selwynii, Salt.	×			×
	Lickapyge cuspidata, Call.			×	
×	*Olenus impar*, Salt.	×			

* Sufficient structural difference exists in Mr. Callaway's specimens to justify his making a sub-genus of the Shineton form, based upon the latrum which is not forked, a character not asaphid. The name *Asaphellus* is proposed by Mr. Callaway.

† The divisions into Lower and Upper Tremadoc are given in the Table on p. 359.

‡ The South Wales species all occur in the St. David's area.

Lingula Flags.	Tremadoc Species.	North Wales.	South Wales.	Shropshire (Shineton).	Pass to Arenig.
	O. Salteri, Call.			×	
	O. triarthrus, Call.			×	
	Psilocephalus inflatus, Salt.	×			
	P. innotatus, Salt.	×			
	Lingula petalon, Hicks		×		
×	*Lingulella Davisii*, M'Coy	×	×		×
	L. Nicholsoni, Call.			×	
×	*L. lepis*, Salt.	×	×		×
	Kutorgina cingulata, Bill.			×	
	Obolella Belti, Dav.	×			
	O. plicata, Hicks.		×		×
×	*O. sagittalis* ? Salt.	×			
	O. Sabrinæ, Call.			×	
	Orthis carausii, Salt.		×		×
×	*O. lenticularis*, Wahl.	×			×
	O. menapiæ, Hicks		×		×
	Davidia ornata, Hicks		×		
	D. plana, Hicks		×		
	Glyptarea Lobleyi, Hicks		×		
	G. primæva, Hicks		×		
	Modiolopsis Cambrensis, Hicks		×		
	M. Homfrayi, Hicks		×		
	M. Ramseyensis, Hicks		×		
	M. Solvensis, Hicks		×		
	Palæarea obloides, Hicks		×		
	P. Hopkinsoni, Hicks		×		
	Ctenodonta menapiensis, Hicks		×		
	C. Cambrensis, Hicks		×		
	Conularia Homfrayi, Salt.	×			×
	Theca alata, Salt. (Centrotheca)	×			
	T. lineata, Call.			×	
	T. arata, Salt.	×			
	T. bigugosa, Salt.	×			
	T. cuspidata, Salt.	×			
	T. Davidis, Hicks		×		
	T. operculata, Salt.	×			
	T. simplex, Salt.	×			
	T. sulcata	×			
	Bellerophon Arfonensis, Salt.	×			
	B. multistriiatus, Salt.	×			×
	B. Shinetonensis, Call.			×	
	B. Ramseyensis, Hicks		×		
	B. Solvensis, Hicks		×		
	Cyrtoceras precox, Salt.	×			
	Orthoceras sericeum, Salt.	×			×

R.E.

Tremadoc Slates.

The formation which immediately succeeds the black Upper Lingula slates, has been already traced as to its course in the preceding chapter. But a few words must be said about this band of slate, which so intimately connects the Lingula flags below with the rocks above, and which is nevertheless so distinct in its fossil characters from either.

If we were to judge by mineral character alone, we should undoubtedly draw the chief line of separation above the hard arenaceous middle Lingula flags, where the peculiar *Lingulellæ* characteristic of that formation become very scarce. Yet the complete zoological change does not take place here, for with the recurrence of the upper black band last described the characteristic genera of the lower zones return, unmixed with those of true Lower Silurian character.

These black slates do not terminate abruptly, but gradually lose their deed tint, and become grey about the horizon of the flags which contain the *Dictyonema*.* This character continues and increases upwards through the beds which contain the fauna tabulated on pp. 358, 359. The beds are also harder, contain flaggy layers here and there, but are not at all coarser, nor otherwise very different from those of the black slate series, except in colour and fossil contents.

The characters of the formation may, as before said, be examined in the sea cliffs of Ogof-ddu near Criccieth, where the harder grey Lower Tremadoc slate, with many lines of ashy material, is seen to overlie and pass down into the upper black slate, full of fossils. But here the Tremadoc series is barren of fossils, and we must refer to the opposite side of the anticlinal axis, and examine the sections near Moel-y-gest, and other places in the Tremadoc district, in order to find the fossiliferous zones.

Lower Tremadoc Slate.

The best localities yet known for fossils are the following:—1. Borthwood, and the meadow slopes on the north side of it, towards the foot of Moel-y-gest, where trilobites and shells are abundant. This mass of rock is let in by extensive faults among the Lingula flags of the neighbourhood, but the escarpment, small as it is, shows an excellent section upwards, from the upper black slate, full of fossils, through the paler Dictyonema flags, to the shell and trilobite beds which cover the top of the hill, and run down its sloping surface to the north.

[On the bye roads that run from Portmadoc to Treflys and the neighbourhood, the grey, often flaggy, but generally dark shaly and thin-bedded Tremadoc slates, and the lighter-coloured and harder beds of Lingula flags below may be easily compared; for they lie close together, and it is not always easy to draw a line between them, the lines of fault bringing them close together without the intervention of the upper black slate, yet the *fossils* are totally distinct.]

2. At the village of Penmorfa the same beds are seen, and are richly fossiliferous. They are dark and earthy, yet not black, or highly pyritous as the Upper Lingula flags usually are, and may be easily followed from a little above the church along the hill side to the new railway (for slates) from Hendre-ddu, Brynkir. There a considerable thickness of the Lower Tremadoc slates comes into view, and the passage downward to the Upper Lingula black slate is not obscure. Above, the section is cut off by faults.

3. A considerable tract of ground running along the west flank of Moel-y-gest exhibits these rocks, but as yet only the lower or intermediate (*Dictyonema*) layers are known to contain fossils. These are plentifully seen at the farm of Cefn Cyfarnedd, and in the walls at Mr. Matthew's seat, Y-Wern.

4. They are seen underlying the Upper Tremadoc beds on the west side of Portmadoc Harbour; and at the rock called Trwyn-Cae-Iago, east of Borth, contains *Psilocephalus innotatus*.

5. East of the estuary, the new road cuttings on the beautiful demesne of Aber-ia reveal fine sections of these beds, which are again conspicuous in the grounds of Castle Deudraeth, and may be traced further east through the rough district skirting the Maentwrog road. They are seen in good sections about the village of Deudraeth, where they are quarried for buildings, and contain the characteristic fossils. They keep the course of the Maentwrog road as far as the turnpike gate, and may thence be followed through the wood and along the course of the railway above Plas Oakley. Above Maentwrog Inn they may also be followed for a while, but their character gradually changes to that of a felspathic slate, in which condition they continue all the way to Ffestiniog. And a little before reaching that village they may be found (at Gelli-fwyog) with the characteristic *Dictyonema* at the base, all but joining the Lingula flags, a very thin band only of the black slate (and that somewhat altered in character) being interposed.

6. But little is known of their east course, but the abundance of the small *Lingullela lepis* in dark earthy slate quarries on the Bala road beyond Pont Nant-y-lladron, in immediate superposition to the Lingula beds, indicates the presence there of the Lower Tremadoc group. They should be sought for

* About 150 feet above the black slate (D. Homfray). This, however, is rather too high an estimate.

along this line, and further southward by Dolgelly. Mr. Salter believed he saw them at Cader Idris in 1865, when examining the gold district.

CHIEF LOCALITIES for LOWER TREMADOC FOSSILS in NORTH WALES.

Cae-Iago near Maentwrog	*Psilocephalus inflatus*	Merionethshire.
	Lingulella lepis	
	L. Davisii	
	Asaphus affinis	
Deudraeth Church	*Niobe Homfrayi*	
Tyn-y-llan	*Niobe Homfrayi*	
	Theca arata	
	T. bigugosa	
	Lingulella lepis	
Penmorfa	*Asaphus Homfrayi**	
	Agnostus princeps	
	Dikelocephalus furca	
	*Conocoryphe vexata**	
	C. depressa	
	*C. versimilis**	
	Psilocephalus inflatus	
	P. innotatus	
	Niobe Homfrayi	
	Ogygia scutatrix	
	*Ceratiocaris insperatus**	
Moel-y-gest	*Dikelocephalus furca**	
Wern	*Conocoryphe depressa*	
Borthwood	*Conocoryphe depressa*	Caernarvonshire.
	Psilocephalus innotatus	
	P. inflatus	
	Niobe Homfrayi	
	Lingulella lepis	
	Theca operculata	
	T. arata	
	T. bigugosa	
Llanerch	*Psilocephalus inflatus*	
	P. innotatus	
	Cheirurus Fredericiٹ	
	Asaphus Homfrayiٹ	
	Niobe Homfrayi	
	Bellerophon arfonensisٹ	
	B. multistriatusٹ	
	Orthoceras sericeumٹ	
	Cyrtoceras precoxٹ	
Ogof-ddu	*Niobe Homfrayi*	
Wern	*Lingulella lepis*	
Tyn-y-dre	*Theca operculata*	
Ty-dynllwyngate	*Psilocephalus innotatus*	
Ty-obry Portmadoc	*Dionide atra*	

R.E.

UPPER TREMADOC SLATE.

The beds into which the dark grey earthy slates last mentioned pass up are not easy to distinguish from the Lingula flag. But they are lighter coloured, often pale grey, and of a flinty texture, occasionally intercalated with ashy layers. Near the top, hard beds of grey sandstone come in, immediately beneath which are the principal beds of fossils, though there are several other fossiliferous lines throughout. Without entering into details of the beds, the following sketch may be given of the distribution of genera through the various parts of the Tremadoc series as well as chief localities. In descending order they are as follows:—

* Passage beds between Lower and Upper Tremadoc.
ٹ All in passage beds between the Lower and Upper Tremadoc.

DISTRIBUTION of GENERA in the TREMADOC ROCKS in N. WALES.

—	Formation.	Localities.	Remarks.
LLANDEILO ROCKS.	15. Ash beds 14. Ashy slate 13. Blue-black fine slate	Llanfrothen Ty-obry Tan-Yr-Allt	No fossils found.
ARENIG GROUP, Sedgw.) (LOWER LLANDEILO, Murch.)	12. Thin layers of black iron-stained slates lying on	Ty-obry	*Dendrograptus* and *Dionide*; *Calymene*; *Æglina*; *Palæarca*.
	11. Thick grits, with some felspathic beds near the base.	Garth Hill, Penrhyn; Ynys-twyn, Portmadoc; flanks of Yr Altwen.	(Beds equivalent to those of the Stiper stones, Shropshire.)
UPPER TREMADOC SLATES. *	10. Hard bluish flags	Garth Quarries, Penrhyn; Pen-bryn-Melyn, Penrhyn; hill side above Deudraeth.	*Lingulella Davisii*; *Angelina*; *Asaphus*; *Cheirurus*; *Oggygia*; *Conularia*; *Orthoceras*; *Linguloearis*; *Centrotheca*.
	9. Soft thin-bedded sandy shales.	Marsh opposite Deudraeth; shore at Minffordd; marshy ground about Tremadoc (by many faults).	—
	8. Hard bluish flat-bedded slate, alternating with many beds of similar slate; but with a "pencil" cleavage and with some flaggy layers.	Penamser, Penrhynllwyd; Tu-hwnt-yr-bwlch.	*Asaphus*; *Theca*; *Orthoceras*; *Conularia*.
	7. *a*†† Thick ash bed Pisolitic iron ore.†	Morfa Lodge, &c.	—
	6. Hard tough beds in a thick series, quarried for building stone at	Portmadoc Quarries	*Theca*; *Oggygia*; *Asaphus*; *Angelina*; *Cheirurus*; *Ampyx*?
	5. Pencil rotchy slate, black, a thick series.	W. side of Portmadoc Harbour	*Lingulella lepis*; *Bellerophon*.
LOWER TREMADOC.	4. Hard blue rock, sometimes almost massive (and with beds and layers of pisolitic iron here and there * * ?); lines of felspathic ash frequent.	Trwyn-cae-Iago; south and east crest of Moel-y-gest; ridges of Borthwood; Plas-yn-y Penrhyn and hills ranging to Deudraeth. (Ynys-Calch and Pen-syflog, with iron ore?)	*Psilocephalus*; *Lingulella lepis*; *Conocoryphe*.
	3. Thick series of iron-stained dark slates passing down into black slate below.	Above Penmorfa Church? railway above Penmorfa; Moel-y-gest, W. side; Borthwood; Aber ia; and various places along the slate railway to Maentwrog.	*Psilocephalus*; *Niobe*; *Theca*; *Conocoryphe*? *Dictyonema*.
	2. Tough bluish beds, only developed locally.	2 miles W. of Penmorfa	*Psilocephalus*; *Dictyonema*? *Oggygia*.
UPPER LINGULA FLAGS.	1. Black slate, about 200 feet thick.	Penmorfa Church; W. side of Moel-y-gest; Carreg Wen, W. of Borth; Aberia; Castle Deudraeth; and various places on the Ffestiniog road.	For fossils, *see* list in pp. 350, 364-369.

The distribution of the *genera* in the zones of the Tremadoc slates is given in the preceding table. The following is a list of most of the species observed in North Wales. At pp. 370, 371 is a separate table of the uppermost beds, which were termed Lower Llandeilo flags, and so described by Sir R. I. Murchison. (They are the Arenig group of Sedgwick.) Those species which are common to the Arenig of North Wales are here inserted in the right-hand column.

* Mr. Hicks proposes to remove the species in the Upper Tremadoc slates to the Arenig group, in which case the terms Lower and Upper Tremadoc have no value in classification or palæontologically, 13 species out of the 29 Upper Tremadoc being common to the Upper Tremadoc and Arenig; this number being about equal to the relationship between the two divisions of the Tremadoc themselves, or 19 in common, out of 69, the whole fauna. Mr. Homfray believes that the Upper Tremadoc rocks at St. David's are represented by the Arenig rocks, which contain many Upper Tremadoc fossils in common, in addition to the rich Graptolite fauna of the same area of Quebec age. R.E.

† There are not two bands of iron ore, but the place of this one is not certain. It may be in the upper position indicated, or it may be in the lower, most probably the former is the correct supposition. The faults are very puzzling here.

TABLE of the LOWER and UPPER TREMADOC GROUPS in N. WALES.

Name and Reference.	Lower Tremadoc.	Passage Beds.	Upper Tremadoc.	Arenig, North Wales.
Annelide tubes - -	Everywhere, as burrows or tracks.		Yr-alt-wen.	
Lingulocaris lingulæcomes. Pl. 10, f. 1, 2.	- - - -	- -	Tuhwnt-y-bwlch, Garth.	
Ceratiocaris? inspératus. Woodcut 6.	- - - -	Penmorfa	——	
C.? latus. Woodcut 5 -	- - - -	- -	Garth.	
Agnostus princeps -	Penmorfa Church -	- -	Penclogwyn.	
Cheirurus Frederici. Pl. 8, f. 1-3.	- - - -	Llanerch	Garth; Penclogwyn -	×
Dikelocephalus furca, head. Pl. 8, f. 9.	Moel-y-gest (Mr. Ash)	——	——	
—— tail of do.? f. 10 (*Nesuretus*).	Penmorfa - -	- -	Penclogwyn.	
Angelina Sedgwicki. Pl. 7.	- - - -	- -	Penclogwyn; Garth; Portmadoc; Tuhwnt-yr-bwlch; Under Garth, &c.; Deudraeth; Ynys-Tywyn.	
Ampyx prænuntius. Pl. 8, f. 5.	- - - -	- -	Penclogwyn.	
Conocoryphe verisimilis. Pl. 6, f. 13.	- - - -	Penmorfa village.	——	
C. olenoides. Pl. 8, f. 6 -	- - - -	- -	Garth.	
C. depressa. Pl. 6, f. 1-3	Wern; Borthwood; Penmorfa.	——	——	
C. invita - - -	Penmorfa Church -	——	——	
C. vexata. Pl. 8, f. 7 -	- - - -	Penmorfa village.	——	
Olenus alatus - -	Penmorfa Church -	——	——	
Olenus impar. Pl. 8, f. 4	- - - -	- -	Penclogwyn.	
Psilocephalus inflatus. Woodcut 8.	Cae-Iago; Llanerch; Penmorfa; Borthwood.	——	——	
P. innotatus. Pl. 6, f. 9-12.	Borthwood; Tydynllwyn Gate; Llanerch.	——	——	
Asaphus Homfrayi. Pl. 8, f. 11-14.	- - - -	Penmorfa village.	Moel-y-gest; Tuhwnt-yr-bwlch; Garth; Penclogwyn.	×
A. affinis. Pl. 8, f. 15 -	- - - -	Llanerch	Tuhwnt-yr-bwlch; Penrhynllwyd; Penclogwyn; Cae Ednyfydd.	×
Niobe Homfrayi. Pl. 6, f. 5-8.	Deudraeth Church; Ogof-ddu; Penmorfa; Borthwood; Tyn-y-llan.	Llanerch field, near house.	——	
Ogygia scutatrix. Pl. 9, f. 1.	Penmorfa road -	- -	Garth; Penclogwyn; Portmadoc.	×
Lingulella Davisii. Pl. 2, f. 7-12; pl. 4, f. 14.	- ? -	- -	Deudraeth; Garth, abundant.	×
L. lepis. Woodcut 11 -	Wern; Borthwood; Trwyn-Cae-Iago, east of Pont-nant-y-lladron, Bala road; Penmorfa Church.	- -	Under Moel-y-gest; Garth.	×
Orthis vaticena - -	Penmorfa - -	——	——	
Bellerophon Arfonensis. Pl. 10, f. 6-8.	- - - -	Llanerch	Moel-y-gest; Garth; Penclogwyn.	
B. multistriatus. Pl. 10, f. 9, 10.	- - - -	id. (Mr. Ash.)	Moel-y-gest - - -	×
Conularia Homfrayi. Pl. 10, f. 11-13.	- - - -	- -	Tuhwnt-yr-bwlch - -	×
Theca (*Centrotheca*) *alata.* Pl. 10, f. 25.	- - - -	- -	Tuhwnt-yr-bwlch; Garth.	
Theca operculata. Pl. 10, f. 22-24.	Borthwood; Tyn-y-dre; Tyn-y-llan.	——	——	
—— *operculum of do.* -	Borthwood; Tyn-y-dre.	——	——	
T. arata. Pl. 10, f. 15, 21.	Borthwood; Tyn-y-llan.	——	——	
T. bijugosa. Pl. 10, f. 19, 20	Do. do.	——	——	
—— sp. - - -	- - - -	- -	Penclogwyn; Garth; Tuhwnt-yr-bwlch; Moel-y-gest.	
Orthoceras sericeum. Pl. 10, f. 4, 5.	- - - -	Llanerch?	Tuhwnt-yr-bwlch; Garth.	
Cyrtoceras præcox. Pl. 10, f. 3.	- - - -	Llanerch.	——	

Perhaps the most characteristic of all the fossils of these rocks are, *Niobe Homfrayi* and *Psilocephalus innotatus* in the lower division, and *Angelina Sedgwickii* and *Asaphus affinis* (or *A. Homfrayi*) in the upper.

Of the above 35 species, five are Lower and Upper Tremadoc and also pass to Arenig. They are *Cheirurus Frederici, Asaphus Homfrayi, A. affinis, Ogygia scutatrix*, and *Bellerophon multistriatus.*

These four trilobites are met with wherever the strata are well seen. The *Niobe* is a large oval species, and has a strong Lower Silurian aspect, with the general appearance of an *Asaphus*, much flattened it is true, but still characteristic, it unites the labrum of an *Ogygia*, and may therefore be considered as intermediate between these genera. *Psilocephalus* again, with its tumid extremities, the head scarcely divided at all into lobes, strongly recalls the aspect of *Illænus*, though it has the characteristic pleuræ of *Asaphus*, and is in many respects intermediate between that genus and *Illænus.*

Agnostus princeps is of the rarest occurrence. But a peculiar form or two of the primordial genus *Conocoryphe*, or of one closely allied to it, are common. The *Conocoryphe depressa* (formerly referred on Barrande's suggestion to *Ellipsocephalus*) is still doubtfully referred to the primæval type. And in all the species above the Lingula flags the generic type is obscure. In this, as in so many cases, the influence of time is rather a thing *felt* by the palæontologist, as he patiently threads his way through a monograph of species, than appreciable by ordinary observers.

With *Agnostus* the Lingulæ have also disappeared from nearly all the lower beds of this formation, although a small and possibly distinct species called *Lingulella lepis*, is abundant enough. But the most characteristic of the shells are the numerous specimens of *Theca*, small triangular pointed shells which no naturalist doubts to have been ancient forms of Pteropod life. One of the species is furnished with an operculum (*T. operculata*), a character detected by Mr. Salter and new in the history of the division of Pteropoda to which *Theca* belongs.

As we rise into the beds called Upper Tremadoc by Salter, some of the species above named linger on awhile, mixed with the new forms of *Orthoceras, Bellerophon*, and *Asaphus*, characteristic of the upper division. But it is only in the passage beds (as seen at Llanerch west of Portmadoc, and south of Garth on the east side of the estuary) that such a mixture has been detected. Penmorfa village,—not the church,—is another locality, and the southern side of the crest of Moel-y-gest mountain contains the same beds.

[On the locality marked Llanerch on the above list, which occurs in two columns, one marked as passage beds, it may be necessary to explain that by the intervention of faults, which range through the farm of Llanerch, all the lower formations are brought up so as to lie within the range of a field or two. This locality is the best known for showing the passage from the Lower Tremadoc slate with *Niobe* and *Psilocephalus* into the upper with Asaphus, Orthoceras, and Bellerophon. At the junction, *Niobe Homfrayi* occurs with the last-named genera in a hard flinty slate.

Mr. Homfray found that at the base occurs *Niobe* and *Psilocephalus*, and further up he finds with *Niobe, Asaphus Orthoceras sericeum, Cyrtoceras*, and *Bellerophon.* Mr. Ash also found there *Cyrtoceras præcox* and *Bellerophon multistriatus.*]

But the true Upper Tremadoc rocks are characterised by a crowd of new species. The *Niobe* and *Psilocephalus* are replaced by *Asaphus* and *Angelina.* The latter indeed is a most remarkable and characteristic fossil, and though allied to *Conocoryphe*, cannot, with reason, be referred to that genus. It is found in the greatest abundance in the rich quarries of Garth, and further eastward towards Deudraeth; and no doubt a search along the flanks of the hills which skirt the vale of Ffestiniog would show it everywhere. With it occur many new species, chiefly the *Asaphus Homfrayi* and *A. affinis*, if those two species be not identical. At Portmadoc quarries it occurs frequently, and west of the town, at the unpronounceable farm of Tu-hwnt-yr-bwlch, good specimens are obtained. *Cheirurus Frederici* more rarely accompanies it in all these places. Agnostus, too, but rarely. Two species of the genus *Conocoryphe*, less characteristic than those of the primordial zone, are found. Even an Olenus, *O. impar*, is present, but so disguised as to look like a species of *Remopleurides.* Lastly, a small *Ampyx* was found by Mr. Ash, to whom we

owe so much of the palæontology of the district. *Nesuretus Ramseyensis* has been found by Prof. Hughes in what are believed to be Tremadoc sandstone at Ty-hen near Llanerchymaedd, in Anglesea. Hitherto *N. Ramseyensis* has not occurred in N. Wales. The shells are as distinct from those of the Lower Tremadoc, as they are from those in the volcanic series above. There are species of *Theca*, but they are distinct from those of the lower beds. One of them is a remarkable form with long projecting spines. There is more than one species of *Bellerophon*; a *Conularia*, as large as any that has yet been discovered elsewhere, of most fragile texture; an *Orthoceras* with close septa, and a curved shell which must be referred to the convenient genus *Cyrtoceras*. It is the earliest known Cephalopod, and is of peculiar interest. It occurs at the base of the Upper Tremadoc, in the beds of passage before referred to.

[Chief Localities for Upper Tremadoc Fossils in North Wales.

Yr-alt-Wen	*Annelide tubes*	Merionethshire.
Tuhwnt-yr-bwlch	*Lingulocaris lingulæcomes*	
	Angelina Sedgwickii	
	Asaphus Homfrayi	
	A. affinus	
	Conularia Homfrayi	
	Theca operculata	
	T. bijugosa	
	Orthoceras sericeum	
Dudreath	*Angelina Sedgwickii*	
	Lingulella Davisii	
Penclogwyn	*Agnostus princeps*	
	Cheirurus Frederici	
	Dikelocephalus furca	
	Angelina Sedgwickii	
	Ampyx prænuntius	
	Olenus impar	
	Asaphus Homfrayi	
	A. affinis	
	Ogygia scutatrix	
	Bellerophon arfonensis	
	Theca bijugosa	
Garth	*Lingulocaris lingulæcomes*	
	Ceratiocaris latus	
	Cheirurus Frederici	
	Angelina Sedgwickii	
	Conocoryphe olenoides	
	Asaphus Homfrayi	
	A. affinis	
	Ogygia scutatrix	
	Lingulella Davisii	
	L. lepis	
	Bellerophon Arfonensis	
	Theca alata (*Centrotheca*)	
	T. bijugosa	
	Orthoceras sericeum	
Portmadoc	*Angelina Sedgwickii*	
	Ogygia scutatrix	
	Agnostus princeps	
Ty-hen, Anglesea	*Nesuretus Ramseyensis?*	
Moel-y-gest	*Asaphus Homfrayi*	Caernarvonshire.
	Lingulella lepis	
	Bellerophon Arfonensis	
	B. multistriatus	
	Theca bijugosa	
Ynys-tywyn	*Angelina Sedgwickii.*	
Cae Edny-fydd	*Asaphus affinis.*	

R.E.

CHIEF LOCALITIES for UPPER TREMADOC SLATE.

Hard bluish flags - - { Garth Quarries. / Penrhyn. / Pen-bryn-melyn. / Deudraeth, hill side above. / Marsh opposite Deudraeth shore. / Minfford, marshy ground about Tremadoc.

Soft, thin bedded, wavy shales - - { Penamser. / Penhynllyoyd. / Tu-hwnt-yr-bwlch.

Thick ash bed iron ore, Morfa Lodge.
Hard tough beds in thick series, quarried for building. Portmadoc quarries.
Pencil slate, black thick series. West side of Portmadoc Harbour.

ARENIG ROCKS.

The Arenig rocks of St. David's are chiefly black slates resting conformably upon the Upper Tremadoc beds stretching from Whitesand Bay eastwards, six or seven miles, and along the north side of the anticlinal. They are well shown at Ramsey Island, faulted against the Harlech group. The Arenigs are about 4,000 feet thick and were undoubtedly acuminated in deep water. Dr. Hicks divides the series into three sub-groups, lower, middle, and upper, the divisions being based chiefly upon palæontological evidence,* the lower possessing 25 species, the middle 28, the upper 33. The groups differ lithologically, the lower are chiefly fine black slates and shales 1,000 feet thick, the middle are slates and flags, banded by sandstones, and about 1,500 feet thick. The upper are fine dark slates, and also about 1,500 feet thick. The mass of the species occurring in the Lower Arenig occur chiefly in the cliffs of Whitesand Bay and at Road-Uchaf in Ramsey Island. No less than 39 species of Rhabdophora and Cladaphora occur in the St. David's Arenig group, distributed through the three divisions as follows, 18 in the lower, 11 in the middle, and 13 in the upper. The characteristic species in the lower series are *Dendrograptus persculpta*, Salt.; *Callograptus radiatus*, Hopk.; *Phyllograptus stella*, Hopk.; *Ptilograptus Hicksii*, Hopk.; *Dictyonema Homfrayi*, Hopk.; and *Trigonograptus ensiformis*, Hall. Equally significant are the Trilobita, species of which characterise the divisions. *Asaphus Homfrayi* and *Ogygia scutatrix* are both Upper Tremadoc and Lower Arenig forms, and tend to link the two series together, and *Lingulella Davisii* here appears for the last time; so with *Orthis lenticularis*, Dalm., which occurs in thousands over the surface of the slabs. *Conularia Homfrayi*, like the Crustacea above named, belongs both to the Upper Tremadoc and Lower Arenig.

The middle or flaggy group is also best seen in Whitesand Bay, near the slate quarries north of Trwyn-hwrddyn, and on the south side of Porth Melgan, immediately south of St. David's Head. It was from these beds in 1860 that Mr. R. Gibbs, late Senior Collector for the Geological Survey, obtained the few species then known, *Trinucleus Gibbsii*, Salt., amongst others. The Lower Arenig of St. David's has yielded only 3 Trilobites, *Asaphus Homfrayi*, *Ogygia scutatrix*, and a *Trinucleus*, the middle division 10, the upper division 11, and conspicuous amongst the middle group are the following characteristic species: *Ogygia bullina*, *O. peltata*, *Æglina grandis*, *Ampyx Salteri*, *Trinucleus Gibbsii*, all confined to this middle series. The Hydrozoa are also peculiar, 11 known, and 8 of the species confined to this horizon; the 12 species of Graptolites in the upper are peculiar to it.

The *Graptolites* occur chiefly in the lower beds of this upper group, and the 3 genera Dendrograptus, Callograptus, and Dictyograptus of the sub-order Cladophora occur and are known only in this area in Wales. The fauna of the middle Arenig of St. David's is also distinguished by its Trilobites, 10 species being all peculiar; this is remarkable. when only 24 occur in the whole

* On the Succession of the Ancient Rocks of St. David's, Arenig, and Llandeilo, &c. Quart. Journ. Geol. Soc. vol. 31, p. 167. 1875.

Arenig group; and for the first time we find the genera *Illænus*, *Illænopsis*, *Phacops*, *Barrandia*, and *Placoparia* appearing, each having a representative species. The occurrence of *Placoparia*, hitherto only known on the same horizon in France, Spain, and Bohemia, is important as bearing both upon distribution and correlation; also for the first time in the British rocks we meet with the Gasteropoda, two species occurring, viz., *Pleurotomaria? Llanvirnensis*, Hicks, and an *Ophileta*. The importance and value of this upper zone of the Arenig group in South Wales is still enhanced by its resemblance to Barrande's *Etage*, D. 1. (in Bohemia), and its strong affinity to the fauna found in the Angers slate in North-west France. Hitherto we have not recognised the presence of this stage and its fauna in Britain; it now enables us to correlate our beds with those of the Continent, and establish a general succession. This result is due to the labour and research of Dr. Hicks, whose able paper upon the succession of the ancient rocks of St. David's, &c., &c., enters fully into the subject.* Carefully constructed tables prepared for the purpose of testing the value of the Arenig group, and its relation to the Tremadoc below and Llandeilo above, clearly, show that it stands almost alone, it being only through 15 species of Hydrozoa out of 42, and 5 species of Trilobites out of 48, that affinity can be said to occur between it and the overlying Llandeilo, although both have so large a Graptolite and Trilobite Fauna.

There are 128 occurrences in the North and South Welsh Arenig beds, 34 in North Wales, and 85 in South, and only 8 are common to the two areas, viz., *Calymene parvifrons*, *Æglina caliginosa*, *Orthis lenticularis*, *Diplograptus dentatus*, *Climacograptus confertus*, *Ogygia Selwynii*, *Homalonotus monstrator*, and *Lingulella Davisii*. *Ogygia scutatrix* does not occur in the North Welsh Arenig beds, only in the Lower Arenig of St. David's and in the Lower and Upper Tremadoc; there is little in common between the Arenigs of Skiddaw and those of North Wales, in which out of 75 species occurring in the Skiddaw and 31 in North Wales only 6 are common, and 4 of these are Graptolites. To compare still further the Arenig of the Stiper Stones area, having 36 species, with those of North Wales, possessing 31, and to which they are geographically related, we find even here only 6 species occurring common to both. The relation however of the species in the Skiddaw beds to the St. David's or South Wales series is closer, no less than 13 being common, and 11 of these are Graptolites and 2 Trilobites. We must bear in mind these are the two largest groups and have been most searched, especially so that of St. David's through Dr. Hicks, and the Skiddaw area by Dr. A. Nicholson, Mr. Dover, and the Survey.

It is important to know that no less than 55 genera make their first appearance in the Arenig group of rocks, viz., 20 Hydrozoa, 4 Annelida, 20 Crustacea, 3 Brachiopod, 6 Mollusca (2 Bivalves, 3 Gasteropod, 1 Pteropod, and 1 Cephalopod). No Hydrozoa are known in the Tremadoc below, 18 genera commence in the lower division, 5 in the middle, and 20 in the upper, and of the 194 Arenig species, 14 only pass to the Llandeilo in any area, and 9 of these are Hydrozoa, 3 Trilobita, and 3 Brachiopoda, and 7 only pass to the Caradoc. Nothing can be more conclusive as to the value of the Arenig group than the distinctive part played by its characteristic fauna and stratigraphical position. The accompanying table shows the complete history of the group in all its phases.

A few fossils, probably of Arenig age, have been collected by J. E. Marr, Esq., of St. John's College, Cambridge,† in some fossiliferous shales on the banks of the Seiont, 1 mile south-east of Caernarvon, from three localities, Point Seiont; along the old tramway from Caernarvon to Nantlle and close to the mill below Peblig Bridge. In the tramway section the Phyllopod crustacean, *Caryocaris Marrii* predominates, the Rhabdophora being almost confined to the Point Seiont section. The Trilobita and Brachiopoda are interesting as indicating their Arenig affinities, added to which *Orthoceras carresiense* is only known in beds of similar age at Llanviran, St. David's, and the genus Caryocaris hitherto has been confined to the Skiddaw Slates of Cumberland (*C. Wrightii* being the type). Again the associated Graptolites here are those of the Skiddaw rocks and area, viz., *Didymograptus bifidus*, *D. indentus*, and

* Quart. Journ. Geol. Soc., vol. xxxi, pp. 167, 195. 1875.

† Q. Journ. Geol. Soc. vol. 32, pp. 134-139, Appendix by Dr. Hicks, who describse two new Crustacea, an Æglina and Caryocaris.

the Llandeilo form *D. Murchisoni*. The genus Barrandia would certainly help to place these beds either in the Arenig or lower part of the Llandeilo group, no species of this genus being recognised lower than the Arenig beds, the Brachiopoda are of little value here, species not being recognisable]. R.E.

The following table exhibits the distribution in time of the entire fauna of the Longmynd and Harlech beds, the Menevian Lingula flags and Tremadoc and those that pass up into the Arenig or are common to that and the older formation below, a separate table is given of the Arenig species occurring at St. David's, as well as those of the Stiper Stones area, Skiddaw, and North Wales: —(R.E.)

DISTRIBUTION of the HARLECH, MENEVIAN LINGULA FLAGS, and TREMADOC SPECIES.

Classes.	Cambrian and Lower Silurian Species, ranging from the Longmynd Group to the Upper Tremadoc.*	Cambrian.	Lower Silurian.							
			Lingula Flags.				Tremadoc.			
		Longmynd, Harlech, Llanberris, St. David's Grits and Sandstones.	Menevian.	Lower Lingula Flags.	Middle Lingula Flags.	Upper Lingula Flags.	Lower Tremadoc.	Passage Beds.	Upper Tremadoc.	Arenig.
PLANTÆ	*None proper.*									
	Oldhamia antiqua, Forbes	—								
	O. radiata, Forbes	—								
PROTOZOA	*Protospongia diffusa*, Salt.	—	S.							
	P. fenestrata, Salt.	S.	S.							
	P. major, Hicks.	—	S.							
	P. flabellata, Hicks.	—	S.							
HYDROZOA	*Bryograptus Callavei*, Lapw.									
ECHINODERMATA	*Dendrocrinus cambrensis*, Hicks.						D.			
	Palæasterina Ramsayensis, Hicks.						D.			
	Protocystites menevensis, Hicks		S.							
	Macrocystella Mariæ, Call.						—			
ANNELIDA	*Tracks of Annelida only*	—								
	Arenicolites / *Scolithus* } *didymus*, Salt.		S.							
	A. uriconiensis, Call.	—								
	A. sparsus, Salt.	—	S.							
	Cruziana semiplicata, Salt.	—								
	Haughtonia pœcila, Kin.	—								
	Histioderma hibernica, Kin.	—								
	Scolicoderma antiquissima, Salt.									
	S. tuberculata, Salt.	—								
	Scolites socialis	—								
	Serpulites fistula, Holl.	—								
	Helminthites	—								
CRUSTACEA TRILOBITA.	*Agnostus menevensis*, Salt.	—	S.							
	A.? Barlowi, Belt.	—					—			
	A. Barrandii, Salt.	—	S. N.							

NOTE.—S. = St. David's or South Wales.
D. = Do. do.
N. = North Wales.
M. = Malvern.

* For all the Tremadoc species *see* table on pp. 357–359, 361.

Classes.	Cambrian and Lower Silurian Species, ranging from the Longmynd Group to the Upper Tremadoc.	Cambrian.	Lower Silurian.							
			Lingula Flags.				Tremadoc.			
		Longmynd, Harlech, Llanberris, St. David's Grits and Sandstones.	Menevian.	Lower Lingula Flags.	Middle Lingula Flags.	Upper Lingula Flags.	Lower Tremadoc.	Passage Beds.	Upper Tremadoc.	Arenig.
CRUSTACEA—*cont.*	*A. Cambrensis*, Hicks.	S.	S.							
	A. Davidis, Salt.		S. N.							
	A. limbatus, Salt.									
	A. Eckbiggi, Hicks.		S. N.							
	A. nodosus, Belt.									
	A. obtusus, Belt.					M.	M.N.		N.	
	A. princeps, Salt.		S.							
	A. scarabæoides, Salt.		S. N.	S.						
	A. scutalis, Salt.					M.				
	A. trisectus, Salt.					M.				
	A. Turneri, Salt.									
	A. venulosus, Salt.									
	A. dux, Call.		S.						N.	
	Arionellus longicephalus, Hicks.								N.	
	Ampyx prenuntius, Salt.									
	Angelina Sedgwikii, Salt.		S.	S.						
	Anopolenus Henrici, Salt.		S.			S.				
	A. Salteri, Hicks.		S. N.							
	A. impar, Hicks.							N.	N.	N.
	Asaphus affinis, M'Coy									
	A. Crofti, Call.							N.	N.	D.
	A. Homfrayi, Salt.								N.	
	Carteocaris insperatus, Salt.								N.	
	C. latus, Salt.							N.	N.	N.
	Cheirurus Frederici, Salt.					N.				
	Conocoryphe abdita, Salt.		S. N.	S.						
	C. applanata, Salt.									
	C. buccephala, Belt.	S.	S.			S.				
	C. Bufo, Hicks.		S. N.				N.			
	C. coronata, Barr.									
	C. depressa, Salt.		S. N.							
	C. Homfrayi, Salt.		S.	S.						
	C. humerosa, Salt.					N.				
	C. invita, Salt.	S.								
	C. Lyellii, Hicks.					M.				
	C. Malvernensis, Phill.	S.								
	C. solvensis, Hicks.									

Classes.	Cambrian and Lower Silurian Species, ranging from the Longmynd Group to the Upper Tremadoc.	Cambrian.	Lower Silurian.							
			Lingula Flags.				Tremadoc.			
		Longmynd, Harlech, Llanberis, St. David's Grits and Sandstones.	Menevian.	Lower Lingula Flags.	Middle Lingula Flags.	Upper Lingula Flags.	Lower Tremadoc.	Passage Beds.	Upper Tremadoc.	Arenig.
CRUSTACEA—*cont.*	*C. longispina*, Belt.								N.	
	C. olenoides, Salt.									
	C. Plantii, Salt.									
	C. simplex, Salt.									
	C. vexata, Salt.							N.	N.	
	C. variolaris, Salt.		S.	S.						
	C. versimilis, Salt.							N.		
	C. Williamsoni, Belt.		S.							
	C. perdita									
	Conophrys salopiensis, Call.					N.				
	Dikelocephalus celticus (*Nesuretus*), Salt.									
	D. discoidalis, Salt.						N.		?N.	
	D. furca, Salt.						N.			
	Dionide atra, Salt.		N.							
	Erinnys venulosa, Salt.		S.							
	Holocephalina primordialis, Belt.		S.							
	H. inflata, Hicks.			N.						
	Hymenocaris vermicauda, Salt.									
	H. major?	S.								
	Leperditia ferruginea		S.							
	L. Hicksii, Jones	S.								
	L. Cambrensis, Hicks.									
	L. primæva									
	Lichapyge cuspidata, Call.		S.							
	Primitia (*Entomis*) *buprestris*, Salt.		S.							
	P. (*Leperditia*) *vexata*, Hicks.		S.	S.					N.	
	P. (*Leperditia*) *solvensis*, Jones.									
	Lingulocaris lingulocomes, M'Coy.		S.	S.		S.				
	Microdiscus punctatus, Salt.	S.								
	M. sculptus, Hicks.						D.			
	Nesuretus Ramsayensis, Hicks.						D.			
	N. recurvatus, Hicks.						D.			
	N. quadratus, Hicks.						D			
	N. elongatus, Hicks.						D.			
	N. var. *obesus*, Hicks.						N.			
	Niobe Homfrayi, Salt.						D.			
	N. Menapiensis, Hicks.									

Classes.	Cambrian and Lower Silurian Species, ranging from the Longmynd Group to the Upper Tremadoc.	Cambrian.	Lower Silurian.						
			Lingula Flags.				Tremadoc.		
		Longmynd, Harlech, Llanberris, St. David's Grits and Sandstones.	Menevian.	Lower Lingula Flags.	Middle Lingula Flags.	Upper Lingula Flags.	Lower Tremadoc.	Upper Tremadoc.	Arenig.
CRUSTACEA—*cont.*	*N. solvensis*, Hicks.						D.		
	Ogygia scutatrix, Salt.						N.	N.	D.
	O. Selwynii, Salt.							N.	N.
	Olenus alatus (*bisulcatus*), Bœck.					N. M	N.		
	O. cataractes, Salt.		?	N.					
	O. flagellifer, Angelin					N.			
	O. gibbosus, Wahl.								
	O. (*sphæropthalmus*) *humilis*, Phil.					M.		N.	
	O. impar, Salt.								
	O. triarthrus, Call.			N.					
	O. micrurus, Salt.								
	O. obesus, Salt.								
	O. pauper, Phill.								
	O. pecten, Salt.					M.			
	O. (*Peltura*) *scarabæoides*, Wahl.					M. N			
	O. Saltei, Call.								
	O. serratus, Salt.								
	O. spinulosus, Wahl.								
	O. truncatus								
	Paradoxides aurora, Salt.	S.	S.			S.			
	P. Davidis, Salt.		N. S.						
	P. Hicksii, Salt.	S.	S.			S.			
	P. Harknessii, Hicks.	S.		S.					
	P Solvensis, Hicks. MS.								
	Plutonia Sedgwikii, Hicks.	S.							
	Psilocephalus inflatus, Salt.						N.		
	P. innotatus, Salt.						N.		
	Carrausia menevensis, Hicks.		S.						
	Palæopygæ Ramsayi, Salt.								
BRYOZOA or HYDROZOA.	*Dictyonema sociale*, Salt.								
BRACHIOPODA	*Discina pileolus*, Hicks.	S.	S.						
	D. cærfaiensis, Hicks.								
	Kutorgina cingulata, Bill.					M.			
	Lingula petalon, Hicks.						D.		D.
	L. squamosa, Holl.								
	L. pygmæa, Salt.								
	Lingulella Davisii, M'Coy			N.			?	N.	
	L. lepis, Salt.						N.	N.	
	L. Nicholsoni, Call.								
	L. primæva, Hicks.	S.							

Classes.	Cambrian and Lower Silurian Species, ranging from the Longmynd Group to the Upper Tremadoc.	Cambrian.	Lower Silurian.						
			Lingula Flags.				Tremadoc.		
		Longmynd, Harlech, Llanberris, St. David's Grits and Sandstones.	Menevian.	Lower Lingula Flags.	Middle Lingula Flags.	Upper Lingula Flags.	Lower Tremadoc.	Upper Tremadoc.	Arenig.
BRACHIOPODA—*cont.*	*L. ferruginea*, Salt. - -	S.	S.						
	L. var. *ovalis*, Hicks. - -								
	Obolella maculata, Hicks. -		S.	S.					
	O. Beltii, Dav. - - -								
	O. sabrinæ, Call. - - -						D.		
	O. (plumbea) plicata, Hicks. -								
	O. Salteri, Holl. - - -								
	O. sagittalis, Salt. - -	S.?	S.	S.					
	Orthis Carausii, Salt. - -						D.	D.	D.
	O. Hicksii, Salt. - - -		S.						
	O. lenticularis, Wahl. - -					N.		N.	D.
	O. Menapiæ, Hicks. - -						D.		D.
LAMELLIBRANCHIATA.	*Davidia crata*, Hicks. - -						D.		
	D. plana, Hicks. - - -						D.		
	Glyptarca Lobleyi, Hicks. -						D.		
	G. primæva, Hicks. - -						D.		
	Modiolopsis Cambrensis, Hicks.						D.		
	M. Homfrayi, Hicks. - -						D.		
	M. Ramseyensis, Hicks. - -						D.		
	M. solvensis, Hicks. - -						D.		
	Palæarca ßloidea, Hicks. -						D.		
	P. Hopkinsoni, Hicks. - -						D.		
	Ctenodonta menapiensis, Hicks.						D.		
	C. Cambrensis, Hicks. - -								
PTEROPODA -	*Cyrtotheca hamula*, Hicks. -		S.						
	Stenotheca cornucopia, Salt. -		S.						
	Theca antiqua, Hicks. - -	S.							
	T. corrugata, Salt. - -		S.	S.					
	T. penultima, Salt. - -	S.	S.						
	T. alata, Salt. - - -							N.	
	T. arata, Salt. - - -						N.	N.	
	T. bijugosa, Salt. - - -						N.	N.	
	T. cuspidata, Salt. - -							N.	
	T. Davidii, Hicks. - -						D.		
	T. menevensis, Salt. - -		S.N.						
	T. obtusa, Salt. - - -								

Classes.	Cambrian and Lower Silurian Species, ranging from the Longmynd Group to the Upper Tremadoc.	Cambrian.	Lower Silurian.						
			Lingula Flags.				Tremadoc.		
		Longmynd, Harlech, Llanberris, St. David's Grits and Sandstones.	Menevian.	Lower Lingula Flags.	Middle Lingula Flags.	Upper Lingula Flags.	Lower Tremadoc.	Upper Tremadoc.	Arenig.
PTEROPODA—*cont.*	*T. operculata*, Salt.						N.		
	T. simplex, Salt.							N.	
	T. stiletto, Salt.		S.						
	T. trilineata								
	Conularia Homfrayi, Salt.							N.	D.
NUELCOBRANCHIATA.	*Bellerophon arfonensis*, Salt.							N.	
	B. cambrensis, Belt.								
	B. multistriatus, Salt.							N.	D.
	B. Ramseyensis, Hicks.						D.		
	B. Solvensis, Hicks						D.		
	B. Shinetonensis, Call.								
GASTEROPODA	*None.*								
CEPHALOPODA	*Cyrtoceras precox*, Salt.						?	N.	
	Orthoceras serriceum, Salt.							N.	D.

R.E.

Above the grits of Garth and Penrhyn, and from that point eastward as far as Arenig Mountain, a still higher set of beds is richly fossiliferous. And as the species in these beds are nearly all of them distinct (with the exception of nine Graptolites, two Brachiopods, and three Trilobites) from those of the true Llandeilo flags, it might be proper to class them partly with the uppermost portion of the Tremadoc formation. But again they are no less distinct from the Upper Tremadoc fossils, only 16 species in the Arenig group being common to the Tremadoc below, which possesses a known fauna of 71 species; they therefore form a distinct and peculiar zone, which fortunately it is easy to recognise. It is entangled in the lower portion of the volcanic grits and ashes which play so conspicuous a part in North Wales.* The table on pp. 358, 359 contains a list, derived from our cabinets and from those of Messrs. Homfray and Ash, but chiefly from the collection made in 1860 by Mr. Salter and our collector, Mr. R. Gibbs. [Since this date the number of species have been greatly augmented through the researches of Dr. Hicks, Mr. D. Homfray, and Mr. Hopkinson at St. David's (Pembrokeshire), and instead of 53 species then known we now possess reliable data for 149, viz., Annelida 11 species, Hydrozoa 42, Crustacea 49, Brachiopoda 18, Lamellibranchiata 6, Pteropoda 8, Nueleobranchiata 6, Gasteropoda 4, Cephalopoda 5, which are distributed through the Skiddaw and Stiper stone beds in England, the Tremadoc, Ty-obry, and Tai-hirion beds of North Wales, and the well-known localities in St. David's Promontory.

The Skiddaw	area possesses	-	-	75 species.
„ Stiper stone	„	„	-	36 „
„ Tremadoc	„	„	-	10 „
„ Ty-obry	„	„	-	24 „
„ Tai-hirion	„	„	-	8 „
„ St. David's	„	(three localities) possesses	-	94 „

* And this is their position also in Shropshire, west of the Stiper stones.

This greater number of appearances being doubtless due to the continued research into the geology of St. David's area. Of the 149 known forms, 16 only are common to the Tremadoc rocks, and 15 pass to the overlying Llandeilo; 117 species of the 149 are peculiar to the Arenig; 3 species only of the 47 Crustacea (*Trinucleus Ramsayi*, *T. Sedgwickii*, and *Homalonotus bisulcatus*) are common to the Llandeilo, and of the 42 Hydrozoa 9 only pass to the same rocks. So with the Brachiopoda, only *Lingula brevis*, *L. attenuata*, and *Orthis calligramma* out of the 19, range into higher strata. Looking at the extensive fauna of certain groups of the Llandeilo rocks and the almost total break in species at the close of the preceding Arenig period, although stratigraphically both formations appear to pass one into the other, yet on palæontological grounds they are totally distinct.—R.E.]

There are no distinct beds of passage with fossils between the Upper Tremadoc and the Arenig, and for this reason:—Everywhere along the Portmadoc district a thick bed of grit (comparable, I believe, only to the Stiper Stone rocks) intervenes to cut off the volcanic upper series from the true Tremadoc slates. This bed of grit, under various conditions, may be traced all along Yr-allt-wen above Tremadoc, and across the estuary; it forms the brow of the Garth, and thence ranges towards the high ground along the curve of the Ffestiniog railway. It is felspathic everywhere, and seems to indicate the commencement of a new state of things, a fact no less plainly indicated by the new fossils introduced. In the Arenig black slates immediately overlying these grits at Garth, we find *Graptolites* in plenty, *Homalonotus*, *Asaphus*, and *Calymene* amongst the trilobites; also *Æglina* and *Dionide*, truly Lower Silurian forms; together with new species of *Conularia*, *Palæarca*, &c.; while a little to the eastward, among the lower parts of the volcanic rocks of the Manod Mountains, we have *Calymene parvifrons* and *Trinucleus Murchisoni*; and still further east these are accompanied by *Ogygia Selwynii*, the fossil above all others which particularises the Arenig rocks of Shelve in Shropshire, and Skiddaw in Westmoreland, and which is also found with other fossils, in a similar slate, in South Carnarvonshire. It is not known as a foreign species.

There is thus no doubt of the horizon of these rocks. They are quite distinct from the Tremadoc rocks of Sedgwick, and were claimed as Lower Llandeilo by Sir R. I. Murchison. They are the Arenig and Skiddaw group of Sedgwick, and have their equivalents, as shown by Salter, in the upper part of the Quebec group of Canada, and probably in the Graptolite shales of Victoria. (*See also* Geology of Canada, p. 932, Montreal, 1863.)

After due consideration a list is here given of the species from Shropshire for the following reasons. Several of them have already been partially described and figured. Some of the more characteristic are given for comparison's sake in pl. 11 A., and lastly it is desirable at once to show that the species of the Tremadoc slate proper (Lower Tremadoc) can no longer be identified with them.

ARENIG ROCKS.

List of Characteristic Arenig Fossils, Wales and Shropshire.*

Name and Reference.	Upper Tremadoc.	N. and S. Wales. (*Lower Llandeilo*). Arenig.	Shropshire. (*Lower Llandeilo*). Arenig.	Llandeilo.
Scolithus linearis. Pl. 11 B, f. 27	- -	- - -	W. of Stiper Stones.	
S. sp. - - - - -	- -	- - -	Do.	
Helmintholithes. Pl. 12, f. 2. -	- -	- - -	Do.	
Encrinite, pentagonal stem, Pl. 11 B, f. 9.	- -	- - -	Do.	
Beyrichia, sp. - - -	- -	- - -	Do.	
Agnostus Morei, n. sp. (Decade ined.)	- -	- - -	Do.	
A. sp. Woodcut 7 - - -	- -	Tai-hirion.	——	

* The Westmoreland species are given in the general table on pp. 378–381. A large series of Rhabdophora occur at St. David's and Ramsey Island, about 30 species being determined by Mr. Lapworth and Mr. Hopkinson, viz., *Trigonograptus* 2 species, *Didymograptus* 8, *Tetragraptus* 4, *Clematograptus*, *Nemagraptus*, *Climacograptus*, *Diplograptus*, and *Phyllograptus* 1 species each, *Dendrograptus* 5, *Ptilograptus* 2, *Callograptus* 3, and *Dictyograptus* 3 species.

Name and Reference.	Upper Tremadoc.	N. and S. Wales. (*Lower Llandeilo.*) Arenig.	Shropshire. (*Lower Llandeilo.*) Arenig.	Llandeilo.
Calymene parvifrons. Pl. 12, f. 3	- -	Ty-obry; Manod-bach; Tai-hirion; Tremadoc.	——	
Ogygia peltata. Pl. 12, f. 8.	- -	St. David's Head.	——	
O. Selwynii. Pl. 9, f. 2–6; pl. 11 B, f. 5.	- -	Tai-hirion; Llan-faelrhys; Hen-gwrt uchaf.	W. of Stiper Stones, (abundant).	
Cheirurus Frederici. Pl. 8, f. 1–3	Garth; Tremadoc.	- - -	Do.?	
Homalonotus bisulcatus - -	- -	Ty-obry.	——	
Æglina caliginosa. Pl. 11 A, f. 10	- -	Ty-obry.	——	
Æ. grandis. Pl. 12, f. 11 - -	- -	St. David's Head.	——	
Æ. binodosa. Pl. 11 B, f. 3.	- -	- - -	W. of Stiper Stones.	
Asaphus affinis - - - -	- -	Ty-obry.	——	
Illænus, sp. - - - -	- -	- - -	W. of Stiper Stones.	
I. perovalis. Siluria, 2d edit., pl. 4, f. 13, 14.	- -	- - -	Do.	
Illænopsis Thomsoni. Pl. 11 B, f. 1	- -	- - -	Do.	
Trinucleus Murchisonæ. Pl. 11 B, f. 4.	- -	- - -	Do.	
Dionide atra. Pl. 11 A, f. 9 -	- -	Ty-obry.	——	
Diplograptus. Pl. 11 A, f. 1, d. e.; pl. 12, f. 1.	- -	Portmadoc; Tai-hirion.	W. of Stiper Stones.	S. Wales.
D. muronatus. Pl. 11 A, f. 6; pl. 12, f. 1.	- -	Ty-obry - -	- - -	Do.
Climacograptus teretiusculus? Pl. 11 A, f. 3.	- -	Do. - -	- - -	Do.
C. bicornis? Pl. 11 A, f. 1 b -	- -	Ty-obry; Ty-ddyn Dicwm.	- - -	Do.
Dicranograptus ramosus? Pl. 12, f. 1; pl. 11 A, f. 1 a.	- -	Do. do. -	- - -	Scotland.
Didymograptus geminus. Pl. 11 B, f. 8.	- -	- - -	W. of Stiper Stones.	
D. hirundo. Pl. 11 B, f. 6, 7 -	- -	St. David's -	Do.	
Monograptus. Pl. 11 A, f. 2. -	- -	Llanfaelrhys -	Scotland.	
Dendrograptus furcatulus. Pl. 11 A, f. 5.	- -	Ty-obry.	——	
Lingulella lepis. Woodcut 11 -	- -	Do.	——	
L. attenuata olim. Pl. 12, f. 7 -	- -	Llanfaelrhys.	——	
Obolella plumbea. Pl. 11 B, f. 10 -	- -	- - -	W. of Stiper Stones.	
O. sp. Pl. 12, f. 6 - - -	- -	Llanfaelrhys.	——	
Discina, sp. - - - -	- -	- - -	W. of Stiper Stones.	
Orthis calligramma. Pl. 11 B, f. 11, 12; pl. 12, f. 5.	- -	- - -	Do. -	N. and S. Wales.
O. sp. (branched ribs). Pl. 11 B, f. 14.	- -	- - -	Do.	
O. alata? Pl. 11 B. f. 13 - -	- -	- - -	Do.	
O. lenticularis - - -	- -	St. David's; Tai-hirion.	——	
Ctenodonta, sp. - - -	- -	Ty-obry.	——	
C. sp. - - - - - -	- -	- - -	W. of Stiper Stones.	
Palæarca amygdalus. Pl. 11 B, f. 17	- -	- - -	Do.	
P. socialis. Pl. 11 A, f. 13 - -	- -	Ty-obry.	——	
Redonia anglica. Pl. 11 B, f. 15 -	- -	- - -	W. of Stiper Stones.	
Ribieria complanata. Pl. 11 B, f. 16	- -	- - -	Do.	
Ophileta. sp. Pl. 11 B, f. 21 -	- -	- - -	Do.	
Theca simplex. Pl. 11 B, f. 22–26 -	- -	- - -	Do.	
T. vaginula. Pl. 10, f. 14 - -	- -	Tai-hirion.	——	
T. sp. - - - - - -	- -	- - -	W. of Stiper Stones.	
Bellerophon hippopus. Pl. 11 B, f. 2.	- -	- - -	Do.	
B. n. sp. - - - -	- -	- - -	Do.	
Conularia corium. Pl. 11 A, f. 11 -	- -	Ty-obry; Garth.	——	
C. margaritifera. Pl. 11 A, f. 12 -	- -	Ty-obry.	——	
Orthoceras Avelinii. Pl. 11 B, f. 18.	- -	- - -	W. of Stiper Stones.	
O. encrinale. Pl. 11 B, f. 19, 20 -	- -	- - -	Do.	
O. sp. - - - - - -	- -	Ty-obry.	——	

In 1843 or 1844 Professor Sedgwick and Mr. Salter collected at Tai-hirion, west of Arenig Mountain, the characteristic *Calymene parvifrons* and *Ogygia Selwynii*. But the species were not properly described by him till 1847. In the same year Professor Sedgwick noticed the occurrence of an *Asaphus* and

some *Graptolites* in the upper beds of what he then termed Tremadoc Slate. But though he saw that the beds lay below the mass of the Welsh slates (Ffestiniog), he did not attempt to bring them into parallel with any of the formations described by Sir R. I. Murchison in his larger work, nor were the fossils then known in Shropshire.

In 1853 Mr. Salter found a small but peculiar fauna in these rocks, distinct both from the Caradoc or Bala beds above them, and from the Llandeilo formation as known elsewhere in Wales. And when in 1859, the 2nd edition of Silurian appeared, the strata were termed Lower Llandeilo by Sir R. I. Murchison, and were made to be equivalents of the lead-bearing rocks west of the Stiper Stones, which rocks are full of fossils.

The list from both these localities was but scanty, but Sir Roderick's and Mr. Salter's researches in the Stiper Stones country had brought to light a large series of fossils distinct from Llandeilo types; and two of these (*Calymene parvifrons* and *Ogygia Selwynii*) were identical with some Mr. Salter had before described from the highest beds (then so called) of the Tremadoc slate. (*See supra.*)

As will be seen by a comparison of the present lists the different stages of the Tremadoc slate were not, in 1853, made out by fossil evidence. Hence the Shelve rocks were necessarily compared with the whole series, and an important point, with regard to the palæontology of the Stiper Stones, was then lost. The age of those rocks (even including the Stiper Stones themselves) could not be greater, and must be less, than that of the Upper Tremadoc, as these are undoubtedly later than the Lingula flags. As the fossil evidence is decisive of this point, so also is the physical structure perfectly explicable on the same view.

[Mr. Callaway believes from later researches and with reason that the quartzites of the Stiper Stones are of Arenig age, and therefore distinct from the quartzites of the Wrekin; when conglomeratic the pebbles of the Arenig quartzite are mainly quartz, while the included fragments of the Wrekin quartz rock are felsitic. Mr. Callaway has also detected the Shineton shales at the base of the escarpment of the Stiper Stones, dipping under the Arenig series in the same direction as the rocks of that formation, i.e., W.N.W. Thus confirming his views as to the position and distribution of the Tremadoc rocks in the Shelve or Longmynd country.*]

Meanwhile, as a point of comparison for the two rocks (and also for the sake of figuring and describing the few species noticed in Siluria), a single plate of Stiper Stones fossils, pl. 11 B, is added, and the identity of several of the species with those of the Arenig rocks will be evident enough.

The strata overlying the Lingula flags in St. David's Bay, Pembrokeshire, were well searched by our collector, Mr. Gibbs; and again in 1862, by Mr. Lightbody, Mr. Salter, and Mr. J. E. Lee, and yielded only a *similar*, not an *identical* series of fossils, and Salter therefore included them with some doubt in the list.† *See* pp. 374, 375, 378–381 for analysis of new St. David's forms.

For the same reasons that have made it desirable to figure and describe a few of the Shelve fossils, figures are added of these,‡ as they certainly occupy a lower horizon than the well-known Llandeilo rocks of other parts of Pembrokeshire.

The few species collected at Llanfaelrhys, Carnarvonshire, occurring in flaggy beds which resemble the Tremadoc slate, are introduced here with little doubt. When first noticed and examined the figures on pl. 12 were believed to be of the age of the Lingula flag. Those from St. David's Head in the same plate, were also regarded as belonging to the upper portions of the Lingula flags, but are now much more properly identified with the Arenig rocks. It is interesting to observe, in a series of beds then comparatively new to science, lying below the true Llandeilo flags and above the Lingula flags and Tremadoc, how great a diversity obtains in localities not far apart, in the fossil contents. The inference is, that a great harvest of undiscovered species still remains to be

* *Vide* Quart. Journ. Geol. Soc., vol.

† They are, however, of types very similar to those of the Arenig or *Lower Llandeilo*, and are undoubtedly distinct from the fauna of the overlying Llandeilo beds of Abereiddy Bay. Mr. Hicks in Quart. Journ. Geol. Soc., vol. xxii., pp. 167-177, has clearly detailed the position, succession, and history of the Arenig rocks of St. David's.

‡ They were originally figured with the "Tremadoc slate or Lower Llandeilo" in Sir R. I. Murchison's work. Siluria, 2d edit., p. 53 Foss. 9.

reaped, and many new beds to be discovered in all these localities. It is not improbable from recent research by Prof. Hughes that the Arenig beds occur at Llangwyllog in Anglesea, six species occurring that are peculiar to that horizon, viz., *Æglina major, Trinucleus Murchisoni, Diplograptus dentatus, Glossograptus ciliatus, Climacograptus confertus,* and *Orthis Carrausii,* the latter being obtained at Treiorweth. Quart. Journ. Geol. Soc., vol. 36, pp. 237–240.

ARENIG of ST. DAVID'S.

[The intimate stratigraphical conformity at St. David's, between the Tremadoc and Arenig rocks, and also the higher and overlying Llandeilo series, is undoubtedly clearly seen both on the dip and along the line of strike of the Cambrian and Silurian series north of the pre-Cambrian ridge or anticlinal, also on the north and east side of Ramsay Island, where both the Tremadoc and Arenig series occupy considerable space. Much of the centre of the island is composed of the Arenig series, and in places prolific in fossils. The Arenig group also occupies an extensive surface area from Whitesand Bay to east of Trevaccoon, a distance of nearly seven miles; numerous Greenstone intrusions occurring along the strike of the beds, the interbedded felspathic tuff also occurring at the junction with the overlying Llandeilo group, and bands of contemporaneous porphyry and felspathic trap accompanying the slates. The rocks here consist chiefly of Black Slates, showing evidence of slow accumulation under deep sea conditions. The thickness of the whole may be 4,000 feet. Mr. Hicks has divided the series into three sub-groups, Lower, Middle, and Upper,* based upon the value of the organic remains in each group, and with relation to the Llandeilo above. This comparison is important here as bearing upon the value, meaning, and application of the terms Arenig and Lower Llandeilo, as applied to at least four areas and groups of rocks in England and Wales, viz., Westmoreland or the Skiddaw group, Shropshire or the Stiper Stones series, North Wales or the Tremadoc and Ffestiniog areas, and South Wales or the St. David's beds. Hitherto the Geological Survey regarded three of the groups in the areas above mentioned as belonging to rocks termed Lower Llandeilo by Sir R. Murchison, and they have been mapped simply as *Llandeilo,* the Survey not recognising the two divisions of lower and upper on the maps, or as separable in the field over large areas. The exact position of the group has for many years been a doubtful question, and it is due to the later continued researches of Messrs. Salter and Homfray in North Wales and Mr. Hicks in South Wales that the name and position assigned to these beds by Professor Sedgwick is now received and definitely established, and that the Arenig group of rocks and fossils have now had assigned to them their true place above the Tremadoc group and below the Llandeilo proper, and with a fauna peculiarly its own. The Llandeilo of Murchison† (first named in 1834) and the Survey does or did not really include any of the Arenig proper as determined in North Wales in 1843, 1846, and in 1852, and as occurring in the chain of the Arenig, Arrans, Cader Idris, and the Ffestiniog region (the typical districts). The term Lower Llandeilo of Sir R. Murchison included Professor Sedgwick's "Arenig" not at first intended, and Professor Ramsay in the first edition of the present memoir‡ states that since 1848 the Geological Survey considered the slates both close below and above the Arrans and Arenigs as equivalent to the Llandeilo flags of Builth and Shelve. Mr. Salter, however, in the first edition of this Appendix in 1866, pp. 255–257, under the section "Lower Llandeilo," and plates 8–12, then clearly showed the importance of rightly and truly correlating the Arenig group, eliminating it partly from the Upper Tremadoc below and the so-called Llandeilo above.

It seems convenient at St. David's to subdivide the group into three series, both on lithological and palæontological grounds. There is, however, no ground for admitting a middle series in the North Wales area, and the upper is one rather of convenience than value.—R.E.]

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* Quart. Journ. Geol. Soc., vol. xxxi., pp. 167–177.

† Proceed. Geol. Soc., vol. ii., p. 13, &c., indicating a series of calcareous flagstone, sandstones, and schists, extensively shown and exposed near Llandeilo and Builth.

‡ Mem. Geol. Survey, vol. iii. (Geol. of N. Wales), p. 6, 1866.

The following Table gives all the species at present known in the Arenig rocks of the St. David's area (South Wales):—

Classes.	Arenig Species at St. David's.	Lower.	Middle.	Upper.	Llandeilo.
Hydrozoa -	*Didymograptus affinis*, Nich. - -			×	
	D. extensus, Hall - - -	×			
	D. bifidus, Hall - - -			×	
	D. furcillatus, Lapw. - - -			×	
	D. nanus, Lapw. (var. of *D. indentus*)			×	
	D. indentus, Hall - - -			×	
	D. Nicholsoni, Lapw. - - -			×	
	D. patulus, Hall - - -		×	×	
	D. pennatulus, Hall - - -	×			
	D. sparsus, Hop. - - -	×			
	Phyllograptus Stella, Hop. - -	×			
	P. typus - - - -				
	Trigonograptus truncatus, Lapw. -	×			
	T. ensiformis, Hall - - -	×			
	Ptilograptus Hicksii - - -	×			
	Dendrograptus arbuscula, Salt. -	×	×		
	D. divergens, Hall - - -	×			
	D. flexuosus, Hall - - -	×	×		
	D. persculptus, Hop. - - -	×			
	D. diffusus, Hall - - -	×			
	Dicellograptus divaricatus, Hall -			×	
	Diplograptus dentatus, Brong. -			×	
	Climacograptus confertus, Lapw. -			×	
	Callograptus radiatus, Hopk. - -	×			
	C. radicans, Hop. - - -	×			
	Clematograptus implicatus, Hop. -		×		
	Tetragraptus bryonoides - -		×		
	T. Halli, Hop. - - -		×		
	T. Hicksii, Hop. - - -		×		
	T. quadribrachiatus, Hall - -		×		
	Glossograptus ciliatus, Emm. - -			×	
	Dictyograptus cancellatus, Hop. -	×			
	D. Homfrayi, Hop. - - -	×			
	D. irregularis, Hall - - -		×		
Crustacea -	*Asaphus Homfrayi*, Salt. - -	×			
	Agnostus hirundo, Salt. - -		×		
	Ampyx Salteri, Hicks - - -		×		
	Æglina grandis, Salt. - - -		×		
	Æ. Boia, Hicks - - -		×		
	Æ. oblusicaudata, Hicks - -			×	
	Barrandia Homfrayi, Hicks - -			×	
	Calymene Hopkinsoni, Hicks - -			×	
	C. parvifrons, Salt. - - -			×	
	C. var. Murchisoni, Salt. - -			×	
	C., sp. - - - -		×		
	Cheirurus, sp. - - -		×		
	Homalonotus monstrator, Hicks -	×			
	Ogygia scutatrix, Salt. - -	×			
	O. peltata, Salt. - - -		×		
	O. bullina, Salt. - - -		×		
	O. Selwynii - - - -	×			
	Illænus Hughesii, Hicks - -			×	
	Illænopsis? acuticaudata, Hicks -			×	
	Placoparia Cambrensis, Hicks -			×	
	Phacops Llanvirnensis, Hicks -			×	
	Trinucleus Gibbsii, Salt. - -		×		
	T. Sedgwickii, Salt. - - -		×		
	T. Etheridgii, Hicks - - -			×	

Classes.	Arenig Species at St. David's.	Lower.	Middle.	Upper.	Llandeilo.
Crustacea —*cont.*	*T. Ramsayi*, Hicks			×	
	T., sp.	×			
	Beyrichia, sp.			×	
Brachiopoda	*Lingulella Davisii*, M'Coy	×			
	Lingula petalon, Hicks	×	×		
	L. attenuata, Sow.			×	
	Dinobolus? Hicksii, Dav.			×	
	Discina, sp.			×	
	Orthis lenticularis, Dalm.	×			
	O., sp.			×	
	O. sp. ? *Carausii*		×		
	Obolella plicata, Hicks	×			
	Siphonotreta		×		
Gastero-poda.	*Ophileta*			×	
	Pleurotomaria Llanvirnensis, Hicks.			×	
Pteropoda	*Conularia Homfrayi*, Salt.	×			
	C. Llanvirnensis, Hicks			×	
	Theca caereesiensis, Hicks			×	
	T. Harknessii, Hicks		×		
Nucleobran-chiata.	*Bellerophon multistriatus*, Salt.		×		
	B. Lanvirnensis, Hicks				
Cephalo-poda.	*Orthoceras sericeum*, Salt.		×	×	
	O. caereesiensis, Hicks			×	

R.E.

Arenig of North Wales.

[The dark grey or Black Slates that overlie or rest upon a definite and now clearly determined band of thick grey grit which has been traced throughout the Tremadoc, Garth, Penrhyn promontory, and Ffestiniog areas, trends away eastward towards the Arenig mountain, and on to Cader Idris on the south-east, are now definitely determined to belong to the Arenig group of Sedgwick. The grit band of variable thickness, though constant in occurrence (save when faulted down for given distances), may be regarded as the top of the Upper Tremadoc or base of the Arenig; better perhaps the latter, no organic remains of any kind have been found in this persistent lithological line from Tremadoc, Traeth Mawr, and Traeth-bach through its entire course to near Towyn south of Cader Idris, where it is lost under the sea. Beneath the grit at Garth Hill and Deudreath occur the upper beds of the "Tremadoc Slates" (*which are hard grey or bluish flags*) with numerous characteristic fossils, *Asaphus Homfrayi, Angelina Sedgwickii, Ogygia scutatrix, Lingulocaris lingulæcomes, Cheirurus Frederici*, and *Conularia corium*, &c., besides other important species, especially large specimens of *Lingulella Davisii*. These hard grey flags at the top of the Tremadoc slates are the beds that some would separate from the Tremadoc series, purely upon palæontological grounds, or because certain species are common to the two horizons, such as *Asaphus Homfrayi, Cheirurus Frederici, Ogygia scutatrix*, and *Bellerophon multistriatus*, &c. Some regard must, however, be had for stratigraphical value and evidence, and such is borne out by the constant and persistent presence of the grit which distinctively and conveniently separates the two horizons palæontologically as well as stratigraphically, the mass of and peculiar fauna of the Arenigs not occurring until the grit is passed. No form of *Graptolite* (*a group essentially characteristic of the Arenig rocks*) is known below this bed of grit in either the Lower or Upper Tremadoc, and although the Arenig *Graptolitidæ* or Rhabdophora are not abundantly shown in North Wales as compared with the Skiddaw area (where about 40 species are known) or South Wales (24 species), still the distinct Crustacean fauna must be held as significant. Again, of the whole Arenig fauna (92 species) in *South Wales* there are only 5 species known in North Wales that are common to the two areas, these are *Calymene parvifrons, Ogygia Selwynii, Æglina caliginosus, Lingulella Davisi*, and *Orthis lenticularis*.

26 Trilobites, 8 Brachiopoda, about 30 Graptolites, and 3 Pteropoda, being peculiar to the St. David's Arenig rocks and confined to that area. Thus amongst the same group of rocks the correlation of species is a difficult question even over so small a geographical area as Wales.

The iron-stained dark slates at Ty-obry which immediately overlies the thick grit contains a rich fauna. Amongst the species of importance are *Calymene parvifrons*, *Æglina caliginosa*, and *Dionide atra*, and for the first time occur in this area many Rhabdophora, *Diplograptus mucronatus*, *Climacograptus teretiusculus*, *C. bicornis*, *Dicranograptus ramosus*, *Dendrograptus furcatulus*.

Lingulella lepis is the common Brachiopod in the beds with the Lamellibranchs *Ctenodonta* and *Palæarca socialis*. *Conularia corium* and *C. margaritifera* are the only Pteropods known. None of the above species pass to the Llandeilo rocks above in any area, neither do they occur in the St. David's Arenig rocks. I append a complete list of the Arenig species of St. David's, arranged in the three groups, lower, middle, and upper, in which it will be seen how distinctive and definite a fauna each group possesses, such as quite to determine us on Palæontological grounds to keep them separate. The whole fauna at St. David's is 81 species; 26 are peculiar or confined to the lower division, 23 to the middle, and 37 to the upper; the occurrences are in each respectively 21, 23, and 34. To show still more conclusively (whatever view may be taken of their deposition and stratigraphical value) the confined or zonal nature of the recognised divisions, only 3 species are common to the lower and middle groups, *Dendrograptus arbuscula*, *D. flexuosus*, and *Lingula petalon*. Neither of these 3 are satisfactory witnesses, and may be open to doubt from such materials. 1 species only, *Didymograptus patulus*, unites the middle and upper divisions; virtually the 3 series are all distinct. I now propose to examine the Arenig group as a whole, showing the distribution of the species both in space and time, and also show the relation of the Arenig fauna to the Tremadoc below and the Llandeilo above. To do this I have selected 18 chief localities to work from, and tabulate 8 (*see* table) of the most important. The 4 type areas where the Arenig rocks are present and characteristically developed are—

1. Westmoreland.
2. Shropshire.
3. North Wales.
4. South Wales.

The most important places for fossils are the following 18, comprising the 4 areas.—

1. Westmoreland	Skiddaw, Longside, Keswick, Outerside, Scawfell, Whiteside, and Braithwaite brow.
2. Shropshire	Shelve area, west of Stiper Stones, Mytton Dingle, Perkins Beech.
3. North Wales	Tremadoc, Garth, Ty-obry, Tai-hirion.
4. South Wales, St. David's	Ramsey Island, Llanviran, Whitesand Bay.

R. E.

CHIEF LOCALITIES in NORTH WALES for ARENIG FOSSILS (*Lower Llandeilo, Murchison*).

Ffestiniog— Manod Ffestiniog	*Calymene parvifrons.*	
Tai-hirion	*Agnostus*, sp.	Merionethshire.
	Calymene parvifrons	
	Ogygia Selwynii	
	Diplograptus pristis	
	Theca vaginula	
	Obolella like plumbea	
	Orthis testudinaria, or ?	
	Calymene parvifrons	
	Æglina caliginosa	
	Dionide atra	
	Diplograptus mucronatus	
	Climacograptus teretiusculus	
	C. bicornis	
	Dicellograptus ramosus	

Ty-obry -	*Dendrograptus furcatula* -	
	Lingulella lepis - -	
	Ctenodonta - - -	
	Palæarca socialis - -	
	Conularia corium - -	
	C. margaritifera - -	
	Theca vaginula - -	
	Orthoceras - - -	
	Dictyonema sociale ? -	
Manod Bach -	*Calymene parvifrons* - -	
Llanfaelrhys (Lleyn)	*Ogygia Selwynii* - -	Caernarvonshire.
	Graptolithus sagittarius -	
	Lingula attenuata - -	
	Fenestella - - -	
Hengwrt uchaf -	*Ogygia Selwynii.*	
Tyddyn Dicwm -	*Diplograptus bicornis.*	
	D. ramosus.	
Tremadoc - -	*Diplograptus pristis ?*	
Anglesea - -	*Illænus Hughesii.*	
	Æglina major.	

SHROPSHIRE, WEST OF STIPER STONES.

Arenig fossils, west of Stiper Stones	*Scolithus* (*arenecolites*) *linearis.*
	S., sp.
	Helmintholithes.
	Encrinite, pentagonal stem.
	Beyrichia.
	Agnostus Morei.
	Ogygia Selwynii.
	Calymene parvifrons.
	Cheirurus Frederici.
	Æglina binodosa.
	Illænus.
	I. perovalis.
	Illænopsis Thomsoni.
	Trinucleus Murchisoni.
	Clematograptus implicatus.
	Diplograptus pristis.
	Didymograptus geminus.
	D. patulus.
	D. Nicholsoni.
	D. constrictus.
	D. hirundo.
	Fenestella.
	Obolella plumbea.
	Discina.
	Orthis calligramma ?
	O., sp., branched ribs.
	O., alata.
	O. striatula.
	Ctenodonta.
	Palæarca amygdalus.
	Redonia anglica.
	Ribieria complanata.
	Ophileta, sp.
	Theca simplex.
	T., sp.
	Bellerophon hippopus.
	B. bilobatus.
	B. perturbatus.
	Orthoceras Avelani.
	O., encrinale.

GEOGRAPHICAL DISTRIBUTION of the ARENIG FOSSILS in ENGLAND and NORTH and SOUTH WALES, showing their relation to the succeeding Llandeilo Group.

Classes.	Tremadoc.	Arenig Species.	SILURIAN. Arenig Group. Westmoreland. Skiddaw, &c.	Shropshire. West of Stiper Stones.†	North Wales.* Tremadoc. Trema-doc Area.	North Wales.* Ty-Obry.	North Wales.* Tal-hirion. Ffestiniog.	South Wales. Llanvirn, St. David's. St. David's.	South Wales. Ramsay Island, Roadstone, Porth-hayog. St. David's.	South Wales. Whitesand Bay, Trwyn-hwrddyn.‡ St. David's.	Llandeilo Group. Llandeilo.	Caradoc.	Lower Llandovery.
HYDROZOA.		*Azygograptus Lapworthi*, Nich.											
		A. cælebs, Lapw.											
		Diplograptus dentatus, Brong.											
		D. Hopkinsoni, Nich.											
		D. mucronatus, Hall											
		Hallograptus bimucronatus, Nich.											
		Phyllograptus angustifolius, Hall.											
		P. typus, Hall											
		P. stella, Hop.											
		Ctenograptus annulatus, Nich.											
		Didymograptus extensus, Hall											
		D. bifidus, Hall											
		D. fasciculatus, Nich.											
		D. pennatulus, Hall											
		D. sparsus, Hop.											
		D. patulus, Hall											
		D. affinis, Nich.											
		D. indentus, Hall											
		D. furcillatus, Lap.											
		D. gibberulus, Nich.											
		D. Murchisoni											
		D. serratulus, Hall											?
		D. nitidus, Hall											
		D. V.-fractus, Salt.											
		D. Nicholsoni, Lap.											
		Tetragraptus bryonoides, Hall.											
		T. Bigsbyi, Hall											
		T. Hallii, Hop.											
		T. Hicksii, Hop.											
		T. quadribrachiatus, Hall											
		T. Headi, Hall											
		T. crucifer, Hall											
		Dichograptus octobrachiatus, Hall.											
		D. Sedgwicki, Salt.											
		D. annulatus, Nich.											
		D. reticulatus, Nich.											
		D. multiplex, Nich.											
		Dendrograptus furcatulus, Salt.											
		D. arbuscula, Salt.											
		D. Hallianus, Prout											
		D. divergens, Hall											
		D. flexuosus, Hall											
		D. persculptus, Hop.											
		D. diffusus, Hall											

* For species occurring in Anglesea, *vide* Prof. Hughes, Quart. Journ. Geol. Soc., vol. xxxvi., pp. 237–240.

† Lord's Hill, Mytton Dingle, Bogmine, Cefn-Gwynelle, Ritton Castle, White Grit Mine, Dinwlfa, Corndon (Shelve area).

‡ And Porth Melgan.

Classes.	Tremadoc.	Arenig Species.	Silurian. Arenig Group. Westmoreland. Skiddaw, &c.	Shropshire. West of Stiper Stones.	North Wales. Tremadoc. Trema-doc Area.	North Wales. Ty-Obry.	North Wales. Tal-hirion. Ffestiniog.	South Wales. Llanvirn, St. David's. St. David's.	South Wales. Ramsey Island, Roseduchan, Porth-hayok. St. David's.	South Wales. Whitesand Bay, Trwyn-hwrddyn. St. David's.	Llandeilo Group. Llandeilo.	Caradoc.	Lower Llandovery.
HYDROZOA—*cont.*		*Callograptus radiatus*, Hop.											
		C. radicans, Hop. - -											
		C. elegans, Hall - -											
		C. Salteri, Hall - -											
		Loganograptus Logani, Hall											
		Dictyograptus cancellatus -											
		D. Homfrayi, Hop. - -											
		D. irregularis, Hall - -											
		Cryptograptus antennarius -											
		C. Hopkinsoni, Nich. - -											
		Clematotograptus implicatus											
		Trigonograptus ensiformis, Hall.											
		T. lanceolatus, Nich. - -											
		T. truncatus, Lapw. - -											
		Trichograptus fragilis, Nich.											
		Dicellograptus - - -											
		D. divaricatus, Hall - -											
		Temnograptus multiplex, Nich.											
		Schizograptus reticulatus, Nich.											
		Climacograptus antennarius											
		C. confertus, Lapw. - -									×		
		C. cælatus, Lapw. - -											
		C. confertus, Lapw. - -											
		C. teretiusculus, His. - -											
		Glossograptus ciliatus, Emm.											
		G. armatus, Nich. - -											
		Pleurograptus vagans, Nich.											
		Ptilograptus Hicksii, Hop. -											
		P. cistula, Hop. - -											
		Thamnograptus Doveri, Nich.											
ANNELIDA.		*Scolithus linearis*, Salt. -											
		Helmintholithes - -											
		Buthotrephis - - -											
		Palæochorda major, M'Coy -											
		P. minor - - -											
		Chondrites acutangularis, M'Coy.											
		C. informis, M'Coy - -											
		Nereites - - - -											
		Scolecoderma - - -											
		Arenicolites - - -											
		Stella-scollites radiatus, Ether.											
CRUSTACEA.		*Caryocaris Wrightii*, Salt. -			*								
		C. marrii, Hicks. - -											
		Agnostus Morei, Salt. - -											
		A., sp. - - - -											
		A. hirundo, Salt. - -											
	×	*Asaphus Homfrayi*, Salt. -							?				
		A. solvensis, Hicks. - -											

* One mile E. of Caernarvon.

Classes.	Tremadoc.	Arenig Species.	Silurian.												
			Arenig Group.									Llandeilo Group.		
			Westmoreland.	Shropshire.	North Wales.			South Wales.						
			Skiddaw, &c.	West of Stiper Stones.	Tremadoc.	Ty-Obry.	Tai-hirion.	Llanvoran, St. David's.	Ramsay Island, Roduchal, Porth-hayog.	Whitesand Bay, Trwyn-hwrddyn.		Llandeilo.	Caradoc.	Lower Llandovery.
					Tremadoc Area.		Ffestiniog.	St. David's.						
Crustacea—cont.		*A. menapiæ*, Hicks.												
	×	*A. affinis*, M'Coy												
	×	*Ogygia scutatrix*, Salt.												
		O. peltata, Salt.												
		O. bullina, Salt.												
	×	*O. Selwynii*, Salt.												
		Trinucleus Gibbsii, Salt.												
		T. Sedgwickii, Salt.												
		T. Etheridgii, Hicks.*												
		T. Ramsayi, Hicks.										×		
		T. Murchisoni, Salt.												
		T., sp.												
		Ampyx Salteri, Hicks.												
		Homalonotus bisulcatus, Salt.										×	×	
		H. monstrator, Salt.												
					?									
		Æglina caliginosa, Salt.												
		Æ. Boia, Hicks.												
		Æ. binodosa, Salt.												
		Æ. grandis, Salt.												
		Æ. obtusicaudata, Hicks.												
		Æ., sp.												
		Barrandia Homfrayi, Hicks.												
	×	*Dionide atra*, Salt.												
		Calymene parvifrons, Salt.												
		C., var Murchisoni, Salt.												
		C. ultima, Salt.												
		C. Tristani, Brong.							†					
		C. vexata, Salt.												
		C. Hopkinsoni, Hicks.												
		C., sp.												
		Phacops Nicholsoni, Salt.												
		P. Llanvirnensis, Hicks.												
		Placoparia Cambrensis, Hicks.												
		Illænus Hughesii, Hicks.												
		I. perovalis, Murch.												
		Illænopsis acuticaudata, Hicks.												
		I. Thomsoni, Salt.												
		Niobe Doveri, Ether.												
		Beyrichia												
		Primitia												
	×	*Cheirurus Frederici*, Salt.												
		C. pectinatus?												
		C., sp.												
Brachiopoda.		*Lingula brevis*, Portl.										×	×	
	×	*L. petalon, Hicks MS.*												
	×	*L. attenuata*, Sow.										×		
	×	*Lingulella Davisii*, M'Coy												
	×	*L. lepis*, Salt.												
	×	*Orthis Carausii*, Salt.												
	×	*O. lenticularis*, Wahl.												
	×	*O. menapiæ*, Hicks.												
		O. alata, Sow.										?		
		O. calligramma, Dalm.										×	×	

* Mr. Tawney has found this species with *Didymograptus bifidus* and *Obolella* at Penarfynydd farm near Rhiw. These with *Ogygia Selwynii*, *Monograptus sagittarius*?, and two species of *Obolella* found at Llanfaelrhys would determine these beds to be probably Arenig.

† A Cornish species—Carn Goran.

Classes.	Tremadoc.	Arenig Species.	Silurian. Arenig Group. Westmoreland. Skiddaw, &c.	Shropshire. West of Stiper Stones.	North Wales. Tremadoc. Trema-doc Area.	Ty-Obry.	Tai-hirion.	Ffesti-niog.	South Wales. Llanveran, St. David's. St. David's.	Ramsay Island, Rondeuchaf, Porth-hayog.	Whitesand Bay, Trwyn-hwrddyn.	Llandeilo Group. Llandeilo.	Caradoc.	Lower Llandovery.
BRACHIOPODA—*cont.*	?	*O. remota*, Salt.		—							—			
		O. striatula, Conrad.		—				—		—	—			
	×	*Obolella plicata*, Hicks.		—						—				
	×	*O. plumbea*, Salt.		—				?		—				
		Discina, sp.		—					—					
		D., sp.	—											
		Siphonotreta micula, ? M'Coy							—					
		Dinobolus Hicksii, Dav.												
LAMELLIBRANCHIATA.		*Ribieria complanata*, Salt.		—							—			
		Modiolopsis trapeziæformis, Salt.		—							—			
		Palæarca socialis, Salt.				—								
		P. amygdalus, Salt.		—										
		C., sp.				—								
		Redonia anglica, Salt.		—										
PTEROPODA.		*Theca Harknessii*, Hicks.									—			
	×	*T. simplex*, Salt.		—										
		T. carecsiense, Hicks.							—					
		T. vaginula (*simplex*), Salt.		—				—	—					
		Conularia Llanvirnensis, Hicks.									—			
	×	*C. Homfrayi*, Salt.								—	—			
		C. corium, Salt.				—								
		C. margaritifera, Salt.				—								
HETEROPODA	×	*Bellerophon multistriatus*, Salt.									—			
		B. hippopus, Salt.		—					—					
		B. Llanvirnensis, Hicks.		—										
		B. bilobatus, Sow.		—										
		B. carinarioides		—										
		B. purterbatus, Sow.		—										
GASTEROPODA.		*Pleurotomaria Llanvirnensis*, Hicks.							—					
		Ophileta							—					
		Raphistoma	—											
		Euomphalus corndensis, Sow*		—										
CEPHALOPODA.	×	*Orthoceras sericeum*, Salt.							—		—			
		O. carecsiense, Hicks.												
		O. Avelani, Salt.		—										
		O. encrinale, Salt.		—										
		O., sp.					—							

R. E.

LLANDEILO ROCKS (Llandeilo flags proper).

The full evidence for the existence of this series of rocks in North Wales is not really complete, as has been shown by Professor Ramsay in the preceding memoir.

Nevertheless a great band of black slate, quarried at many points for roofing slate (Ffestiniog Quarries, &c.), has been described by Sedgwick and by the

* The species in the Durness Limestone may be of this age.

Survey as underlying the Bala or Caradoc strata, and thus occupying a position equivalent to that of the Llandeilo flags, and it is probable that the lower series of the Llandeilo group may occur in the Arenig and Ffestiniog Mountains and also in the Arrans. It is of interest, if possible, to prove its equivalent by fossil forms. Unfortunately, the materials are but scanty, but a fossil found near Bangor and others in the slates which overlie the Arenig porphyries, are identical with those of the Llandeilo rocks elsewhere; and one or two of the species do not agree with those of any higher formation.

Mr. Salter included the black slates of Anglesea, though there is some little doubt if they are the equivalents of the dark earthy slates east of Arenig Mountain. There are certain species in them which are but rarely found in Llandeilo strata, *e.g.*, the *Asaphus Powisii* and *Phacops apiculatus;* but the former is certainly found, though rarely, in Llandeilo flags in South Wales.

The multitudes of a dwarf variety of *Orthis calligramma*, pl. 22, which give a Caradoc aspect to the grits, are not at all exclusive, for a similar assemblage is to be found in the volcanic Llandeilo grits of Builth. And the Graptolites strongly remind us of the Llandeilo flags. Indeed *Climacograptus* (*Diplograptus*) *teretiusculus** in higher beds is not known.

LLANDEILO FOSSILS IN NORTH WALES.

Name and Reference.	NORTH WALES.	Other Llandeilo Localities in Wales.	Remarks on other Localities.
Favosites fibrosa, Goldf. Siluria, 2d ed., pl. 40, figs. 6, 7.	Garn, E. of Arenig; S. side of Arenig; 1 mile N.W. of Llanerchymedd; Treiorwerth.	Pembrokeshire	Wexford, in Llandeilo rocks.
Favosites (large tubes) - -	Fron-oleu, 3 miles S.E. of Llangefni, Anglesea.	——	——
Ischadites, sp. Woodcut, f. 4. -	Garn, E. of Arenig -	- - -	A similar one in the Caradoc of Sweden.
Encrinite rings, abundant, and of several species.	Craig-y-glyn, near Llanrhaidr.	——	——
Diplograptus pristis. Pl. 11 A, fig. 1, d e; pl. 12, fig. 1.	Conway - - -	S. Wales.	——
D. ramosus. Pl. 12, fig. 1; pl. 11 A, fig. 1, a.	Do. - - -	- - -	Scotland.
Climacograptus teretiusculus. Pl. 11 A, fig. 3.*	Conway; Glan-y-gors, 3 miles E. of Llanerchymedd.	Pembrokeshire.	——
Didymograptus Murchisoni? Siluria, 2d ed., pl. 1, fig. 1.	Carnedd-Dafydd; Pont Seiont, Carnarvon.	Pembrokeshire; Builth.	——
Ampyx mammillatus. Port. Geol. Rep., pl. 1 B, figs. 1, 2,	Garn, Arenig - -	- - -	Waterford.
Phacops apiculatus. Siluria, foss. 13, fig. 3.	1 mile N.W. of Llanerchymedd; Treiorwerth.	——	——
Asaphus tyrannus. Pl. 13, figs. 1-7	Craig-y-glyn - -	S. Wales.	——
Asaphus Powisii, Murch. Pl. 15 -	1 mile N.W. of Llanerchymedd; Treiorwerth.	——	——
Cybele, sp. - - - - -	Arenig, S.E. side -	S. Wales.	——
Trinucleus concentricus, var. *favus*. Pl. 13, fig. 9.	Craig-y-glyn - -	Do.	——
Calymene Blumenbachii, var. *cambrensis*. Pl. 17, figs. 13, 14.	Craig-y-glyn; 1 mile N.W. of Llanerchymedd; Treiorwerth.	S. Wales; Shropshire.	——
Æglina major. Decade 7, G. Surv. Pl. 10, f. 9.	Glan-y-gors; 3 miles S.E. of Llanerchymedd.	——	——
Siphonotreta micula. Siluria, 2d ed., foss. 10, fig. 17.	Conway - - -	S. Wales.	——

* *C. teretiusculus* is found at Gogofau, S. Wales, most probably in Llandeilo flags (Professor Ramsay, 1864).

Name and Reference.	North Wales.	Other Llandeilo Localities in Wales.	Remarks on other Localities.
Lingula, sp. - - - -	Glan-y-gors, 3 miles S.E. of Llanerchymedd.	—	—
Orthis resupinata. Siluria, pl. 6. figs. 1-3.	Craig-y-glyn - -	S. Wales.	—
O. carinata. M'Coy, Pal. foss., pl. 1. figs. 20-24.	Do. - - - -	—	—
O. testudinaria. Siluria, 2d ed., foss. 34. fig. 2.	Arenig, S. side - -	Shropshire.	—
O. Actoniæ. Pl. 21. figs. 1-5 -	Garn, Arenig - -	- - -	Wexford, in strata probably Llandeilo.
O. calligramma, var. Pl. 22. f. 1 -	1 mile N.W. of Llanerchymeld: Trecastell: Tyn-twr, 4 miles S. of Llanrwst.	—	—
—— sp., crenulated ribs. *O. striatula*?	Garn, and S. side of Arenig.	- - -	*O. striatula*, Wexford.
O. elegantula, Dalm. Siluria, pl. 5. fig. 5.	Tyn-twr, 4 miles S. of Llanrwst.	—	—
O. insularis, Siluria, 2d ed.; Eichw. Geol. Russ., iii. p. 3. fig. 7.	Garn - - -	- - -	Plentiful in the Caradoc rocks.
O. bifurcata. Siluria, 2d ed., foss. 33. fig. 4.	S. side of Arenig -	S. Wales -	Wexford.
Strophomena rhomboidalis (*tenuistriata*). Siluria, pl. 5. fig. 13.	Pr n-oleu, 3 miles E. of Llanrwst.	—	—
Leptæna 5-costata. Siluria, foss. 34. fig. 3.	Garn, and S. side of Arenig.	- - -	A Caradoc species.
Ctenodonta, sp. - - -	Garn.	—	—
Maclurea? rather a small species -	Conway.*	—	—
Bellerophon perturbatus. Woodcut 16.	Bangor - - -	S. Wales.	—
B. bilobatus. Siluria, p. 7. fig. 9 -	Garn - - -	Do.	—
—— sp., fine lines of growth -	Do.	—	—
Orthoceras, fragments - -	Do.	—	—

It should be observed in reviewing this list, that supposing these beds to be of the age of the Llandeilo flags, we have the genus *Ischadites*, which is probably a regularly formed sponge, lower down than it has ever been before detected. Even in Caradoc rocks it is but rare.

Of the *Ampyx mammillatus* little can be said. It occurs in Waterford among species which seem to be rightly referred by their discoverer, Major Austin, to the Llandeilo age; but in Sweden it is a Carodoc fossil. The *Trinucleus favus*, a var. of *T. concentricus*, is only known in Llandeilo rocks, and occurs both in North and South Wales, and the same is true of the variety termed *cambrensis* of the equally common *Calymene Blumenbachii*. Some would be disposed to regard this as a distinct species. There can be no objection to that view. *Asaphus tyrannus* is a well-known form peculiar to these deposits. *Æglina major*, *Diplograptus ramosus*, *Climacograptus teretiusculus*? and *Siphonotreta micula*, are all Llandeilo forms. The two latter species are also Arenig.

Bellerophon perturbatus occurs very rarely in Caradoc rocks, but it is one of the commonest fossils in the Llandeilo flags. The Brachiopoda, on the other hand, have a wide range, and are all mostly common to the two deposits. They are the most widely distributed of all the Silurian forms, a fact in their history long known, and ably commented on, by Forbes, Sharpe, Davidson, Salter, Suess, and other naturalists.

On the whole, we cannot doubt the existence of the Llandeilo flags in North Wales, but Professor Ramsay's explanation of their local distribution, as the result of their unconformity to the rocks below, receives additional value from the suggestion that they may be unconformably covered by the Caradoc strata; and that their occasional re-appearance from beneath that formation, as at Conway and other places, may in this way be satisfactorily explained. There is no other mode of interpreting the facts. For we cannot doubt that the cliff of black slates at Conway, hemmed in closely by Caradoc and Wenlock rocks, is a fragment of the old formation; and if the *Maclurea* be rightly determined, it must be so.

* Mr. Darbishire's collection, Manchester.

[Large as the Llandeilo fauna is known to be in South Wales, I believe only about 50 reliable species are known to occur in North Wales, and this out of 175 recognised species; 56 species have been obtained from the Llandeilo beds of Abereiddy Bay, one of the chief localities in South Wales; 18 species only are known to be common to North Wales and the St. David's area, they are *Favosites fibrosa, Asaphus tyrannus, A. Powisii, Calymene cambrensis, Trinucleus concentricus, Diplograptus pristis, Didymograptus Murchisoniæ, Siphonotreta micula, Orthis vespertilio, O. proava, O. turgida, O. striatula, O. elegantula, O. simplex, O. insularis, Bellerophon perturbatus,* and *B. bilobatus.*

Mr. Hicks divides the Llandeilo series proper, of St. David's into three sub-groups, lower, middle, and upper, both on physical and palæontological grounds. The fauna of the lowest sub-group is essentially hydrozoal, 10 or 12 of the 22 known species being Graptolites, many confined, with *Calymene Murchisoniæ, Trinucleus Ramsayi,* and *Theca caresiensis,* which also do not occur higher. The middle sub-group "consists of calcareous shales and flags, and at the top tolerably compact limestone"; 24 species are known from this middle division, 9 Graptolites, 8 Crustacea, 4 Brachiopoda, 2 Corals, and *Bellerophon perturbatus.*

The characteristic Crustacea in this middle division are, *Asaphus tyrannus, A. peltastes, Calymene cambrensis, Trinucleus Lloydi, Ogygia convexa,* and *Lichas patriarchus,* all being confined to it.

Black argillaceous shales and flaggy sandstones constitute the chief feature in the lithological characters of the upper sub-group. From these beds in the slate quarry in 1874 Prof. Ramsay and myself obtained *Lingula Ramsayi, Barrandia Cordai, Calymene duplicata, Trinucleus fimbriatus, Ogygia Buchii, Bellerophon perturbatus,* and *Diplograptus pristis.* The species in this upper division are nearly all peculiar or palæontologically different from the middle series. Of the 50 species occurring in the three sub-divisions of the Llandeilo at St. David's, only eight are known in the succeeding Caradoc in Wales; they are the following, and I give them as being important for reference when the question of distribution is again carefully considered: *Lingula attenuata,* Sow.; *Lingula granulata,* Phill.; *Bellerophon perturbatus,* Sow.; *Diplograptus foliaceus,* Murch.; *Diplograptus pristi?* His.; *Orthis striatula,* Conrad; *Ampyx nudus,* Murch.; and *Calymene duplicata,* Murch. I shall have occasion to refer again to the Llandeilo species when considering the distribution of the Caradoc of North Wales and Britain generally.] R.E.

Llandeilo Rocks, St. David's.

[As before stated, the fossils of this group of rocks is not well developed in North Wales, and the species comprising the fauna are scanty and unsatisfactory, and out of the 175 species known in the Llandeilo rocks proper, only 47 occur in North Wales, 18 of these are Brachiopoda, 15 Crustacea, and 7 Hydrozoa. These three groups we should expect would be largely represented.

In the St. David's area and throughout Pembrokeshire, Breconshire, and Carmarthenshire, at the typical localities, Llandeilo and Builth they are finely developed, and contain a special fauna; at Aber-eiddy Bay they are black slates and argillaceous limestones, about 2,500 feet thick, interstratified with felspathic tuff, resting upon the Arenig group, which everywhere here underlies it, but with a distinct fauna. The junction of the two formations is physically marked and determined by a thick bed of tuff. Commencing W. of Aber-pwll and ranging eastwards, the presence and abundance of *Didymograptus Murchisoni* and *Diplograptus foliaceus* in the slates of the southern side of Aber-eiddy Bay, above the felspathic tuff, at once fixes the base of the Llandeilo series; species of *Dendrograptus* (*D. Ramsayi*) and *Ptilograptus* (*P. acutus*) also occur. Anglesea has yielded several Llandeilo species, no less than eleven being known from Treiorwerth. Mr. Hicks,* as above stated, divides the series into three groups, lower, middle, and upper; the lower composed of black slates, &c., being finely exposed in the cliffs at the S. side of Aber-eiddy Bay, and is essentially characterised by *Trinucleus Ramsayi,*

* Quart. Journ. Geol. Soc., vol. 31, pp. 177, 195.

	North Wales.	South Wales.	Common to North and South Wales.
Actinozoa	1	2	1
Echinodermata	—	1	—
Annelida	—	1	—
Crustacea	15	29	8
Hydrozoa	8	18	13
Brachiopoda	18	26	13
Lamellibranchiata	1	4	1
Gasteropoda	1	1	—
Heteropoda	2	2	2
Pteropoda	—	2	—
	46	86	40

Thus 132 species, as far as we know, are Welsh, and 40 as at present determined are common to or palæontologically unite the two areas called North and South Wales.

The most important of these 40 species are the following:—*Parasites fibrosa*, *Asaphus tyrannus*, *A. Powisii*, *Calymene cambrensis*, *C. Blumenbachii*, *Trinucleus*

concentricus, T. favus, Oxygia Portlockii, and *Beyrickia complicata, Diplograptus foliaceus, D. tricornis, D. dentatus, Dicranograptus ramosus, D. formosus, D. Nicholsoni, Climacograptus cælatus, C. schrenbergi, C. teretiusculus, C. confortus, C. bicornis, Crania divaricata, Leptæna tenuissimestriata, L. sericea, Cardiola interrupta, Berychia complicata, Didymograptus Murchisoni, Orthis vespertilio, O. proava, O. turgida, O. striatula, O. simplex, O. elegantula, O. insularis, O. biforata, Strophomena rhomboidalis, Siphonotreta micula, Bellerophon perturbatus, B. bilobatus.*

The chief localities in North Wales are Garn, E. of Arenig, Merioneth, Glan-y-gors, Treiorworth, and Llanerch-y-medd in Anglesea, Conway, Craig-y-Glyn, and Tiddyn-Dicum.

The Llandeilo rocks of Scotland yield about 70 species; Ireland 50.]

R.E.

TABLE of Llandeilo Fossils in Aber-eiddy Bay, St. David's.

——	Llandeilo Species.	South Wales.		
		Lower.	Middle.	Upper.
HYDROZOA.	*Didymograptus Murchisoni*, Beck	×	×	?
	D. Nicholsoni	×	×	
	D. indentatus, Hall	×		
	D. var. *nanus*, Lapw.	×		
	D. euodus, Lapw.	×		
	Diplograptus rugosus, Emm.		×	
	D. foliaceus, Murch	×	×	×
	D. tricornis, Carr. (*Cryptograptus*)	×	×	×?
	D., per excavatus, Lapw.			×
	Cænograptus gracilis (*Hælicograptus*)		×	
	Nemagraptus, sp.	×	×	
	Cryptograptus tricornis, Carr.	×		
	Dicellograptus Moffatensis, Carr.		×	×
	D. patulosus, Lapw.		×	
	Dendrograptus serpens, Hop.	×		
	D. Ramsayi, Hop.	×		
	Dicranograptus forosmus, Hop.		×	×
	Glossograptus Hincksi	×		
	Climacograptus cælatus, Lapw.	×	×	×
	C. Scharenbergi, Lapw.			×
	C. confertus		×	
	Ptilograptus acutus, Hop.	×		
ACTINOZOA.	*Halysites catenularia*, Linn.		×	
	Favosites (*Stenopora*) *fibrosus*		×	
CRUSTACEA.	*Asaphus tyrannus*, Murch.		×	
	A. peltastes, Salt.		×	
	Agnostus M'Coyi, Salt.			×
	Ampyx nudus, Murch.			×
	Acidaspis, sp.			×
	Æglina, sp.			×
	Æ., sp.	×		
	Barrandia Cordai, M'Coy			×
	B. longifrons, Edgell			×
	Calymene duplicata, Murch.			×
	C. Murchisoni?, Salt.	×		
	C. cambrensis, Salt.		×	
	Cheirurus Sedgwickii, M'Coy			×
	Ogygia, sp.	×		
	O. convexa, Salt.		×	
	O. Buchii, Brong.			×

—	Llandeilo Species.	South Wales.		
		Lower.	Middle.	Upper.
CRUSTACEA—*cont.*	*O.* sp. - - - - -			×
	Lichas patriarchus, Edgell - -		×	
	Trinucleus Ramsayi, Hicks - -	×		
	T. Lloydii, Murch. - - -		×	
	T. favus, Salt. - - -		×	
	T. fimbriatus?, Murch. - -		×	×
	T., sp. - - - -			×
BRACHIOPODA.	*Lingula Ramsayi*, Salt. - -			×
	L. attenuata, Sow. - - -	×	×	
	L. granulata, Phill. - - -		×	
	Orthis striatula, Conrad - -		×	
	Leptæna sericea, Sow. - -		×	
	Siphonotreta, sp. - - -	×		
PTEROPODA.	*Theca caerecsiensis*, Hicks - -	×		
	T., sp. - - - -			×
NUCLEOBRANCHIATA.	*Bellerophon perturbatus*, Sow. -	×	×	×
CEPHALOPODA.	*Orthoceras*, sp. - - -			×

CHIEF LOCALITIES for LLANDEILO FOSSILS in NORTH WALES.

Garn, E. of Arenig	*Favosites fibrosa* - -	Merionethshire.
	Ischadites, antiquus - -	
	O. antiquus - - -	
	Ampyx mammillatus - -	
	Orthis actoniæ - -	
	O. calligramma - -	
	O. striatula? - -	
	O. insularis - - -	
	Leptæna quinquicastata -	
	Ctenodonta - - -	
	Bellerophon bilobatus -	
	B., sp. - - -	
	Orthoceras - - -	
Arenig, S. side -	*Orthis spiriferoides* - -	
	O. biforata - - -	
1 mile N.W. of Llaerch-y-medd -	*Favosites fibrosa* - -	
	Phacops apiculatus - -	
	Asaphus Powisii - -	
	Calymene Blumenbachii, var. *cambrensis* - -	
	Orthis carausii? - -	
Glan-y-gors, 3 miles S.E. of Llanerch-y-medd - -	*Monograptus* - -	
	Climacograptus teretiusculus?	
	Ægliua major - -	
	Lingula - - -	
Treiorwerth - -	*Favosites fibrosa* - -	Anglesea.
	Phacops apiculatus - -	
	Asophus Powisii - -	
	Calymene Blumenbachii, var. *cambrensis* - -	
	Orthis calligramma? carausii	
Fron-olen, 3 miles S.E. of Llangefni, Anglesea - -	*Favosites (large tubes)* -	
	Strophomena rhomboidalis -	
Tyn-tur, 4 miles S. of Llangefni - -	*Orthis calligramma* - -	
	O. elegantula - -	

Pont-sciont (Carnarvon) - -	*Didymograptus Murchisoni* -	
Conway - -	*Diplograptus* - -	
	Climacograptus teretiusculus?	
	Siphonotreta micula - -	
	Maclurea, small sp. - -	
Carnedd-Dafydd -	*Diplograptus Murchisoniæ* -	
Bangor - -	*Bellerophon perturbatus* -	
Tyddyn Dicum -	*Lasiograptus bimucronatus* -	Caernarvonshire.
	Thamnograptus typus -	
	Diplograptus dentatus -	
	D. angustifolius - -	
	D. Whitfieldi - -	
	Didymograptus ramosus -	
	D. superstes - - -	
	Diplograptus tricornis -	
	Climacograptus Scharenbergi	
	C. bicornis and vars. -	
	Glossograptus Hincksi -	
Craig-y-Glyn, near Llanrhyadir -	*Encrinital stems* - -	Denbighshire.
	Asaphus tyrannus. - -	
	Trinucleus concentricus -	
	Calymene Blumenbachii, var.	
	Orthis vespertilio - -	
	O. turgida - - -	R.E.

FAUNA of the LLANDEILO ROCKS.

Classes.	Arenig. Lower.	Arenig. Middle.	Arenig. Upper.	Llandeilo Species.	Localities. England.*	North Wales.	South Wales.	Scotland.	Ireland.	Pass to Caradoc.
RHIZOPODA -				*Ischadites antiquus*, Salt. - -						
HYDROZOA -				*Diplograptus acuminatus*, Nich. -						
				D. foliaceus, Murch. - - -						×
				D. angustifolius, Hall - - -						×
				D. dentatus, Brong. - - -						
				D. confertus, Nich. - - -						×
				D. Etheridgii, Hop. - - -						
				D. amplexicaulas - - -						
				D. Harknessii, Nich. - - -						
				D. Hincksii, Hop. - - -						
				D. penna, Hop. - - - -						
				D. pennatus, Hark. - - -						
				D. perexcavatus, Lapw. - -						
				D. persculptus, Salt. - - -						
				D. pinguis, Hop. - - -						
				D. Euglyphus, Lapw. - - -						
				D. insectiformis, Nich. - -						
				D. cometa, Gein. - - -						
				D. quadrimucronatus, Hall - -						×
				D. tamariscus, Nich. - - -						×
				D. tricornis, Carr. - - -						
				D. Whitfieldi, Hall - - -						
				Gymnograptus Linnarssoni, Lapw. -						
				Glossograptus Hincksii, Hop. -						

NOTE.—The column marked North Wales indicates the fauna of the Llandeilo rocks in North Wales, and the Caradoc column those species probably common to the two formations.

Many Hydrozoa confined either to Ireland or Scotland are not all given here as reference is chiefly confined to Wales. It would have exceeded the object and scope of this Appendix to have merely listed all the Scotch and Irish species that had no comparison with North Wales, Lapworth, Nicholson, and Hopkinson have exhaustively studied the Rhabdophora. For fullest research see their papers in the Quart. Journ. of the Geol. Soc. and Geol. Mag., *passim*.

* Chiefly stiper stones area (Shropshire).

Classes.	Arenig. Lower.	Arenig. Middle.	Arenig. Upper.	Llandeilo Species.	Localities. England.	Localities. North Wales.	Localities. South Wales.	Localities. Scotland.	Localities. Ireland.	Pass to Caradoc.
HYDROZOA—*cont.*				*Dawsonia complanata* Nich.						
				Didymograptus Murchisoni, Beck.						
				D. serratulus, Hall						
				D. euodus, Lap.						
				D. Nicholsoni, Lap.						
				D. superstes, Lap.						
				Rastrites capillaris, Carr.						
				R. Barrandii, Hark.						
				R. maximus, Carr.						
				R. Linnæi, Barr.				?		?
				Reteolitus venosus, Hall						
				Dicranograptus ramosus, Hall						×
				D. formosus, Hop.						
				D. Nicholsoni, Hop.						×
				D. rectus, Hop.						
				Dendrograptus sp.						
				D. Ramsayi, Hop.						
				D. ramulus, Hop.						
				D. serpens, Hop.						
				Dicellograptus elegans, Carr.						
				D. intortus, Lapw.						
				D. anceps, Nich.						
				D. divaricatus, Hall						
				D. Morrisii, Hop.						
				D. patulosus, Lap.						
				D. sertans, Hall						
				Amphigraptus radiatus, Lapw.						
				Climacograptus bicornis, Hall						
				C. innotatus, Nich.						
				C. cælatus, Lap.						
				C. confertus, Lap.						
				C. Scharenbergi, Lap.						×
				C. tuberculatus, Nich.						
				Clathrograptus cuneiformis, Lapw.						
				C. gernitzianus						
				Cœnograptus gracilis, Hall						
				C. sercularis, Hall						
				C. Pertonius, Lapw.						
				C. explanatris, Lapw.						
				Hallograptus bimucronatus, Nich.						
				H. mucronatus						
				Lasiograptus Harknessii						
				L. fimbriatus Hop.						
				L. bimucronatus, Nich.						
				C. teretiusculus, His.						×
				Corynoides calicularis, Nich.						
				C. gracilis, Hop.						
				Nemagraptus capillaris, Emm.						
				Clathrograptus cuneiformis, Lap.						
				Pleurograptus linearis, Carr.						
				Protovirgularia dichotoma, M'Coy						
				Ptilograptus acutus, Hop.						×
				Thamnograptus typus, Hall						
CŒLENTERATA				*Halysites catenulatus*, Linn.						×
				Favosites fibrosa, Goldf.						×
				Monticulipora favulosa, Phill.						×
ECHINODERMATA.				*Actinocrinus Wynnei*, Baily						
				Glyptocrinus basalis, M'Coy						
				Echinosphærites granulatus, M'Coy					?	×
				Palæasterina Kinchani, Baily						×
ANNELIDA				*Nereites cambrensis*, Murch.						×
			—	*Palæochorda major*, M'Coy } *West-*	} Probably Arenig.					
			—	*P. minor*, M'Coy } *more-*						
				P. teres, Hark. } *land.*						
				Salterella Maccullochii, Salt.						
				Serpulites dispar, Salt.						×
				S. Maccullochi, Salt.						
				Trichoides ambiguus, Hark.						
				Pyritonema fasciculus, M'Coy						
CRUSTACEA				*Peltocaris aptychoides*, Salt.					?	
				Dicinocaris Browniana						
				Acidaspis Jamesii, Salt.						×

Classes.	Arenig. Lower.	Arenig. Middle.	Arenig. Upper.	Llandeilo Species.	Localities. England.	Localities. North Wales.	Localities. South Wales.	Localities. Scotland.	Localities. Ireland.	Pass to Caradoc.
CRUSTACEA—*cont.*	—			*Homalonotus bisulcatus*, Salt.		—				× ×
				Illænus Bownanii, Salt.	—			—		× ×
				I. Murchisoni, Salt.			—			
				Lichas patriarchus, Edgell			—			
				Salteria involuta, Thom.				—		
				S. primæva, Thom.				—		
				Agnostus M'Coyii, Salt.			—			
				Ampyx mammillatus, Sars.		—			—	× ×
				A. rostratus, Sars.		—		?		× ×
				A. nudus, Murch.			—			× ×
				Ogygia angustissima			—			
				O. (Barrandia) Portlockii, Salt.		—			—	
				O. corndensis, Murch. (*Asaphus*)	—		—			
				O. Buchii, Brong.	—		—			
				O. convexa, Salt.	—		—			
				Stygina Murchisoniæ, Murch.			—			
				Phacops apiculatus, Salt.		—				× ×
				P. truncato-caudatus, Portl.					—	× ×
				Asaphus tyrannus, Murch.		—	—			
				A. peltastes, Salt.	—		—			
				A. laticostatus, M'Coy			—			
				A. Powisii, Murch.		—	—			×
				A. hybridus, Salt.			—			
				Calymene cambrensis, Salt.	—	—	—			
				C. duplicata, Murch.			—		—	×
				C. Blumenbachii?, Brong.		—	—			× ×
				C. brevicapitata, Portl.	—					× ×
				Trinucleus fimbriatus, Murch.			—			× ×
				T. Lloydii, Murch.	—		—			
				T. concentricus, Eaton	—		—			×
	—		—	*T. Ramsayi*, Hicks			—			
				T. Edgelli, Salt.		—				
				T. favus, Salt.		—	—			
				Cheirurus Sedgwickii, M'Coy			—			
				Barrandia longifrons, Edgell			—			
				B. radians, M'Coy (*Ogygia*)			—			
				B. Cordai, M'Coy			—			
				Æglina major		—				
				Æ. mirabilis, Salt.			—		—	
				Beyrichia complicata, Salt.	—	—	—			× ×
				B. Barrandiana, Jones						
				Primitia bipunctata, Salt.						
BRACHIOPODA				*Acrotreta Nicholsoni*, Dav.				—		× ×
				Crania divaricata, M'Coy		—	—		—	× ×
				Discina crassa, Hall			—	—		× ×
				D. Portlocki, Gainitz				—	—	
				Rhynchonella Edgelliana, Dav.		—				
				Siphonotreta micula, M'Coy		—		—		×
				S., sp.			—			
				Lingula Ramsayi, Salt.			—			
				L. curta, Conrad			—			
	—		—	*L. attenuata*, Sow.		—	—			× × ×
	—			*L. brevis*, Portl.	—		—		—	× ×
				L. obtusa, Hall			—			
				L. granulata, Phill.	—		—			×
				Obolella plumbea, Salt.			—			
			—	*Orthis alata*, Sow.			—			
				O. remota, Salt.		—				
				O. vespertilio, Sow.	—	—	—			× × ×
				O. turgida, M'Coy		—	—			× × ×
				O. spiriferoides, M'Coy	—	—	—			× × × ×
				O. Actoniæ, Sow.	—	—	—		—	× × × ×
				O. testudinaria, Dalm.	—	—	—	—	—	× × ×
				O. simplex, M'Coy			—		—	
			—	*O. calligramma*, Dalm.		—	—	—	—	× ×
				O. striatula, Conrad		—	—	—	—	× × ×
				O. confinis, Salt.		—	—	—		× × ×
				O. elegantula, Dalm.		—	—		—	× × × ×
				O. insularis, Eichw.		—	—	—		× × × ×
				O. biforata?, Schloth.		—	—		—	× × × ×
				Strophomena corrugatella, Dav.		—	—			× × × ×
				S. rhombridalis, Wilck.		—	—			× × × ×
				Leptæna quinquecostata, M'Coy		—	—			× × × ×
				L. tenuissimestriata, M'Coy		—	—			× × ×
				L. sericea, Sow.		—	—			× × ×
				L. tenuicincta, M'Coy		—				× ×

Classes.	Arenig. Lower.	Arenig. Middle.	Arenig. Upper.	Llandeilo Species.	Localities. England.	North Wales.	South Wales.	Scotland.	Ireland.	Pass to Caradoc.
LAMELLI-BRANCHIATA.				*Modiolopsis expansus*, Portl.			—			×
				M. inflata, M'Coy			—			×
				Ctenodonta varicosa, Salt.			—			
				Palæarca amygdalus, Salt.			—			
				Pleurorhynchus calcis, Baily					—	
				Cardiola interrupta, Sow.		—	—			×
GASTEROPODA				*Cyclonema crebristria*, M'Coy	—	—				×
				Euomphalus corndensis? Sow. (Shelve)	—					?
				E. matutinus, Hall				—		
				E. parvus, Portl.					—	
				Murchisonia angulocincta, Salt.				—		
				M. angustata, Hall				—		
				M. bellicincta, Salt.				—		
				M. gracilis, Hall				—		
				M. simplex, M'Coy			—			×
				Turbo tritorquatus, M'Coy					—	×
				Ophileta compacta, Salt.				—		
				Pleurotomaria Thule, Salt.				—		
HETEROPODA				*Ecculiomphalus scoticus*, M'Coy				—	—	×
				Maclurea Logani, Salt.				—		
				M. magna, Leseur				—		?
				M. Peachii, Salt.				—		
				M. macromphala, M'Coy				—		×
				Bellerophon perturbatus, Sow.		—	—			×
				B. bilobatus, Sow.	—	—	—			×
CEPHALOPODA				*Cyrtoceras multicameratum*, Hall				—		
				Endoceras eoum, Edgell			—			
				Orthoceras arcuoliratum, Hall				—		×
				O. avelani?, Salt. (Shelve)	—					
				O. mendax, Salt.				—		
				O. undulostriatum, Hall				—		
				O. vertebrale?, Hall				—		
				Piloceras invaginatum, Salt.				—		
PTEROPODA				*Theca reversa*, Salt.			—			×
			—	*T. cærecensis*, Hicks			—			
				T. cometoides, Baily					—	

R.E.

CARADOC (OR BALA) ROCKS.

The following lists contain all the species which have come under our notice from the area now described.* It will be at once seen how rich a formation the Caradoc or Bala formation is in the North Welsh district. And by comparison with other and well-known localities, the Mollusca and Crustacea of this district will be found, as above said, to agree perfectly over wide tracts of country.

The fauna is very different from that of the Llandeilo flags: Graptolites, so common in the Arenig and Llandeilo schists, are rare in the coarse and sandy material of the Caradoc—only 36 species known, 15 of which are from the Llandeilo, and as none pass to the higher beds, the Graptolite fauna is only 15 for Wales at least; the Trilobites are of different species and many distinct genera. The Brachiopoda only, which appear to be generally indifferent to the nature of the sea bottom, are nearly identical. Still greater differences would appear, were we to compare the whole Caradoc fauna, here so rich, with other districts of the true Llandeilo age, where fossils are also

* Including (with Prof. M'Coy's name attached to them) fossils mentioned only in the Cambridge Synopsis, such species having been chiefly collected by Prof. Sedgwick and Mr. Salter in 1843 and 1844, the localities being well known to him.

abundant. As the one formation is clearly superposed upon the other, and as every here and there the same mineral conditions recur in either formation, without much resemblance in their fossil contents, we are compelled to regard the considerable difference in the fauna as due chiefly to age.

This applies only in part to the Llandeilo formation, which has several species identical with the Caradoc. The Arenig, though frequently arenaceous, has but nine species in common, and four of these are Graptolites.

It must be remarked that the localities given for the more common species are only general ones. Our survey lists, derived from an immense collection made under the direction of the late Sir H. De la Beche, are crowded with localities, of which it is only thought necessary to give the leading districts in which they are grouped, so as to show the range. For the less common fossils, all the separate localities are given. The succeeding list, and that given at pp. 406–423, convey to the student of Silurian geology through North Wales, South Wales, and England all the chief and important localities ever searched and collected during the progress of the Survey, and now tabulated to show their geographical distribution. R. E.

List of North Welsh Caradoc Fossils arranged Zoologically and Geographically.

Name.	Reference to other Works.	Locality.
Fucoids? pl. 14, f. 5, 6 -	- - -	*Merionethshire.*—Bala Lake.
Protozoa (*Sponges*).		
New sponge, spicula of -	- - -	*Montgomeryshire.*—Llanfylliu.
Stromatopora striatella, D'Orb.	Siluria, pl. 41. fig. 31.	*Montgomeryshire.*—Llanwddyn.
Cælenterata.		
Favosites alveolaris, De Blainville.	Siluria, pl. 40, figs. 1, 2.	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.* — Llanfyllin ; Meifod ; Llangedwyn. *Merionethshire.*—E. of Bala Lake.
F. Gothlandica, Linn. -	Ib., figs. 3, 4 -	*Denbighshire.*—S. of Llangollen.
F. (*Stenopora*) *fibrosa*, Goldf.	Ib., figs. 6, 7 -	*Caernarvonshire.* — Moel Siabod ; Carnedd Dafydd ; Penmachno ; Llyn Idwal ; E. of Y-Tryfan ; Dolwyddelan. *Denbighshire.*—S.E. of Cerrig-y-Druidion ; S. of Llangollen ; Cyrn-y-brain, Wrexham. *Montgomeryshire.* — Llanwddyn ; Welshpool ; Meifod ; Llanfyllin. *Merionethshire.*—E., W., and S.E. of Bala Lake ; Corwen.
—— var.? *ramulosa*, Phill.	Phillips, in Mem. of Geol. Survey, vol. ii., pt. 1, p. 307.	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Merionethshire.*—W. of Bala.
F. (*Stenopora*) *Lycopodities*, Say.	Hall, Pal. N. York, vol. i., pl. 23, figs. 1–3.	*Caernarvonshire.*—Conway. *Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Meifod, &c. *Merionethshire.*—Bala.
Nebulipora favulosa, Phill. var. *lens*, M'Coy. Pl. 19, fig. 10.	- -	*Caernarvonshire.*—Bettws-y-coed ; Dolwyddelan. *Montgomeryshire.* — Welshpool ; Meifod. *Denbighshire.*—Cerrig-y-Druidion. *Merionethshire.*—E.W. and S.E. of Bala Lake ; N. of Bala ; W. of Corwen.

Name.	Reference to other Works.	Locality.
Chætetes petropolitanus, Pander.	Murchison's Russia, vol. ii., pl. A., fig. 10.	*Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—E. and W. of Bala Lake.
Heliolites interstincta, Wahl.	Siluria, pl. 39, fig. 2.	*Denbighshire.*—Glyn Ceiriog; S. of Llangollen. *Montgomeryshire.*—Llanfyllin.
H. megastoma, M'Coy, var. with prominent calices.	Siluria, p. 203, fig. 7.	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Meifod. *Merionethshire.*—Bala.
H. tubulata, Lonsdale -	Siluria, pl. 39, fig. 3.	*Montgomeryshire.* — Allt-goch, Llanfyllin.
Petraia æquisulcata, M'Coy.	Pal. foss., pl. 1 B., figs, 23, 24.	*Denbighshire.* — Glyn Ceiriog (M'Coy). *Montgomeryshire.*—Llanfyllin.
P. uniserialis, M'Coy -	Ib. - -	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.* — Meifod (M'Coy).
P. rugosa, Phill. -	Pal. foss., p. 7 -	*Montgomeryshire.* — Meifod (M'Coy).
P. subduplicata, M'Coy	Siluria, p. 204, fig. 3.	*Denbighshire.* — Cyrn-y-brain; Wrexham; Glyn Ceiriog; S. of Llangollen.
Petraia, sp. - -	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion; S. of Llangollen. *Merionethshire.* — S.E. of Bala Lake. *Montgomeryshire.*—Llanfyllin.
[*P. elongata*, Phill. -	Siluria, pl. 38, fig. 6.	*Merionethshire.* — Bala (M'Coy) very doubtful.]
Halysites catenularius, Linn.	Siluria, pl. 40, fig. 14.	*Denbighshire.*—S. of Llangollen. *Montgomeryshire.*—Meifod.
Omphyma turbinata, Linn. ?	Siluria, pl. 39, fig. 11.	*Denbighshire.*—S. of Llangollen.
Cyathophyllum, sp. -	- -	*Montgomeryshire.*—Llanfyllin.
Aulopora, large and small sp.	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion.
ANNELIDA.		
Tentaculites anglicus, Salter.	Siluria, 2nd ed., pl. 1, fig. 3.	*Caernarvonshire.*—Pwllheli; Carnedd Dafydd. *Merionethshire* and *Montgomeryshire.*—Llanfyllin; Llanwddyn; E. and W. of Bala Lake. *Denbighshire.*—Glyn Ceiriog, S.E. of Cerrig-y-Druidion.
Cornulites serpularius, Schloth.	Ib., pl. 16, fig. 3, 10 -	*Caernarvonshire.*—E. of Y-Tryfan. *Denbighshire.* — S.E. of Cerrig-y-Druidion.
Serpulites longissimus, Murch?	Ib., pl. 16, fig. 1 -	*Montgomeryshire.*—Llanwddyn, in the Berwyn Mountains.
Serpulites (cylindrical sp.).	- - -	*Merionethshire.*—E. and W. of Bala Lake.
Scolecoderma (see Appendix). Pl. 14, fig. 1–4.	- -	[The tubes lie horizontally in the rock, and are slightly curved upwards.]
—— sp., quite flattened -	- - -	*Merionethshire.*—W. of Bala Lake, N. of Bala.
—— another sp. with cylindrical tubes (figs. 1–4).	- - -	*Merionethshire.*—W. of Bala Lake.
Scolites, worm burrows -	- - -	Everywhere in arenaceous rocks.

Name.	Reference to other Works.	Locality.
ECHINODERMATA.		
Cystidea.		
Sphæronites Litchi, Forbes. Pl. 20, figs. 3, 4.	Mem. Geol. Survey, vol. ii., pt. 2, pp. 413–538.	*Merionethshire.*—W. of Bala Lake?
S. munitus, Forbes. Pl. 20, fig. 5.	- - -	*Do.* do.
S. pyriformis, Forbes. Pl. 20, figs. 1, 2.	- - -	*Do.* do.
S. punctatus, Forbes. Pl. 20, fig. 7.	- - -	*Do.* do.
Sphæronites, two or three other species undescribed.	- - -	*Do.* do.
Echinosphærites balticus, Eichw. Pl. 20, fig. 10.	- - -	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—W. of Bala Lake.
E. (*Caryocystites*) *Davisii*, M'Coy. Pl. 20, fig. 9., *Caryocystites granatum*, Forbes, not of Wahlenberg.	Mem. Geol. Survey, vol. ii., pt. 2, pl. 21, fig. 4.	*Caernarvonshire.* — Yspytty Evan (M'Coy). *Denbighshire.*—S. of Llangollen. *Merionethshire.*—W. of Bala Lake; Rhiwlas, Bala.
E. aurantium, Gyll.? Pl. 20, fig. 6.	- - -	These are introduced for comparison, but are only known in Pembrokeshire, S. Wales.
E. arachnoideus, Forbes. Pl. 20, fig. 8.	- - -	
Glyptocystites (n. genus, Billings), sp. undescribed.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion.
Hemicosmites squamosus, Forbes.	Mem. Geol. Survey, vol. ii., pt. 1, pl. 20, fig. 1.	*Montgomeryshire.*—Near Llanfyllin.
H. pyriformis, V. Buch.? Pl. 20, fig. 12.	- - -	*Merionethshire.*—Rhiwlas, Bala.
H. oblongus, Pander. Pl. 20, fig. 11.	- - -	[Introduced for comparison.] In Pembrokeshire, S. Wales.
Pleurocystites, sp. (with rhombs, three on one side). For figure of genus, pl. 23, fig. 5.	- - -	*Merionethshire.*—Rhiwlas, Bala.
Undetermined genera of *Cystideæ*.	- - -	*Denbighshire.*—Cerrig-y-Druidion. *Merionethshire.*—N. and E. of Bala Lake.
Crinoidea.		
Glyptocrinus? basalis, M'Coy. Pl. 23, fig. 4.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. of Bala Lake. *Montgomeryshire.*—Meifod.
Heterocrinus, sp. -	- - -	*Montgomeryshire.*—Meifod.
Asteroidea.		
Palæaster asperrimus, Salter. Pl. 23, fig. 2.	- - -	*Montgomeryshire.*—Quakers' Burial Ground, near Welshpool; Guilsfield.
P. obtusus, Forbes. Pl. 23, fig. 1.	- - -	*Merionethshire.*—W. of Bala Lake.
P. imbricatus, n. sp. Pl. 23, fig. 8.	- - -	*Montgomeryshire.*—Llanfyllin.

Name.	Reference to other Works.	Locality.
Edrioaster Buchii (*Agelacrinus*, Forbes). Pl. 20, fig. 13.	- - -	*Caernarvonshire.* — Near Yspytty Evan.
Protaster Salteri, Forbes. Pl. 23, fig. 3.	- - -	*Denbighshire.*—Cerrig-y-Druidion.
CRUSTACEA (TRILOBITA).		
Agnostus trinodus, Salter. Pl. 19, fig. 8.	- - -	*Merionethshire.*—W. of Bala Lake. *Denbighshire.* — S. and S.E. of Cerrig-y-Druidion.
Agnostus, sp. - -	- - -	*Merionethshire.*—W. of Bala Lake.
Acidaspis Brightii, Murch.	Siluria, Pl. 18, figs. 7. 8.	*Denbighshire.*—S. of Glyn Ceiriog (Woodw. Mus.).
Ampyx tumidus, Forbes. Pl. 23, fig. 6. Woodcut 9.	- - -	*Montgomeryshire.*—Near Llangynnog (M'Coy). *Merionethshire.*—Rhiwlas, Bala.
Asaphus Powisii, Murch. Pl. 15, figs. 1–5.	- - -	*Caernarvonshire.* — Dolwyddelan; Bettws-y-coed; Moel Siabod. *Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.* — Llanwddyn; Meifod; N. of Llangedwyn; Llanfyllin; Welshpool. *Merionethshire.*—E. and W. of Bala Lake.
Asaphus radiatus, Salter (*Asaphus laticostatus*, M'Coy, not of Green), Pl. 23, f. 7.	Pal. Foss. Woodw. Mus., pl. 1 E., fig. 18 only.	*Montgomeryshire.*—Llanfyllin. *Denbighshire.* — S. of Cerrig-y-Druidion.
Calymene Blumenbachii, Brong. (*C. subdiademata*, M'Coy), chiefly if not wholly the var. *Caractaci*. Pl. 17, figs. 1–2.	- - -	*Caernarvonshire.* — Near Pwllheli (M'Coy); Dolwyddelan. *Denbighshire.*—S. of Llangollen; S. of Cerrig-y-Druidion. *Merionethshire.*—E. of Bala Lake. *Montgomeryshire.*—Llanwddyn.
C. senaria, Conrad (*brevicapitata*, Portl.). Pl. 17, figs. 8–12.	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion; Cyrn-y-Brain; Nant-y-brain, Wrexham (M'Coy). *Merionethshire.* — E., W.. and S.E. of Bala Lake; N. of Bala. *Montgomeryshire.*—N. of Llangedwyn; Llanfyllin; Llanwddyn; Meifod.
Cheirurus bimucronatus, Murch. Pl. 18, figs. 4–7.	- - -	*Merionethshire.*—E. and W. of Bala Lake.
C. juvenis, Salter. Pl. 18, figs. 1, 2.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—N. and W. of Bala Lake, about Rhiwlas especially; Corwen (M'Coy). *Montgomeryshire.*—Llanfyllin.
C. octolobatus, M'Coy. Pl. 18. fig. 3.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—Rhiwlas (M'Coy). [Also occurs in Ayrshire, Scotland.]
Cybele rugosa, Portlock	Pal. Foss. M'Coy, Pl. 1 G., fig. 8.	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—W. of Bala Lake. *Montgomeryshire.* — Meifod (M'Coy).

Name.	Reference to other Works.	Locality.
C. verrucosa, Dalm.	Ib., pl. 1 G., fig. 1–5.	*Caernarvonshire.* — Carnedd Dafydd. *Denbighshire.* — S. of Cerrig-y-Druidion. *Montgomeryshire.* — Llanwddyn ; Llanfyllin.
Cybele, sp.	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin.
Encrinurus sexcostatus, Salt. Pl. 19, figs. 5–7.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—N. and W. of Bala Lake.
Homalonotus bisulcatus, Salter. Pl. 16, figs. 1–8.	- - -	*Caernarvonshire.*—Carnedd Dafyd ; Pwllheli ; Bettws-y-coed ; Dolwyddelan. *Denbighshire.* — S.E. of Cerrig-y-Druidion ; Capel Garmon. *Montgomeryshire.*—N. of Llangedwin ; Llanwddyn ; Llanfyllin ; Meifod. *Merionethshire.*—N. of Bala ; E., W., and S.E. of Bala Lake.
H. rudis, Salter. Pl. 16, figs. 9–11.	- - -	*Denbighshire.*—Capel Garmon.
Illænus Bowmanni, Salter, Pl. 18, fig. 8.	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—Llanfyllin.
I. Davisii, Salter. Pl. 18, fig. 9.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—E., W., and N. of Bala Lake ; W. of Corwen.
Lichas laxatus, M'Coy, Pl. 19, figs. 1–3.	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Merionethshire.*—E. and W. of Bala Lake. *Montgomeryshire.* — Llanfyllin ; Llanwyddyn.
Lichas, sp.	- - -	*Denbighshire.* — S.E. of Cerrig-y-Druidion.
Phacops alifrons, Salter	Ib., pl. 1 G., fig. 12	*Caernarvonshire.*—Penmachno Hill (M'Coy). *Denbighshire.* — Capel Garmon (M'Coy). *Merionethshire.* — W. of Corwen (M'Coy). *Montgomeryshire.*—Meifod.
P. apiculatus, Salter	Ib., figs. 17–19	*Caernarvonshire.*—Pwllheli. *Denbighshire.* — S. and S.E. of Cerrig-y-Druidion ; Glyn Ceiriog (M'Coy) ; near Llangollen. *Montgomeryshire.* — Llanfyllin ; Llanwddyn ; Meifod. *Merionethshire.*—E. and W. of Bala Lake.
P. conophthalmus, Beck.	Ib., fig. 22 (not 23)	*Caernarvonshire.*—Bettws-y-coed. *Denbighshire.* — S.E. of Cerrig-y-Druidion ; Glyn Ceiriog (M'Coy). *Montgomeryshire.* — Llanwddyn ; Meifod.

Name.	Reference to other Works.	Locality.
P. macroura, Sjogren, (*truncatocaudatus*, M'Coy, not Portl.).	Pal. Foss. t. 1 G., fig. 21.	*Denbighshire.*—Glyn Ceiriog; S. of Llangollen (M'Coy).
P. Brongniartii, Portl. -	Portl. Geol. Rep., pl. 2, fig. 8.	*Merionethshire.*—W. of Bala Lake. *Montgomeryshire.* — Llanwddyn; Llanfyllin.
P. mucronatus, Brong. -	Bront. t. 3, fig. 9 -	*Merionethshire.*—W. of Bala Lake.
Remopleurides Colbii, Portl.	Decade 7, pl. 8, fig. 1.	*Do.* do.
R., new sp., allied to *R. radians*, Barr.	Barrande, pl. 43, fig. 33.	*Do.* do.
R. longispina? Portl. -	Portl. Geol. Rep. -	*Do.* do.
Remopleurides, large sp.	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion.
Staurocephalus Murchisoni, Barr.	Barr., pl. 43, fig. 28	*Merionethshire.*—Rhiwlas; Bala.
Trinucleus concentricus, Eaton. Pl. 19, fig. 4.	- - -	*Caernarvonshire.* — Pwllheli (M'Coy); Conway; Carnedd Dafydd; Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S. of Cerrig-y-Druidion. *Montgomeryshire.* — Llangedwyn; Meifod; Llanfyllin; Llanwddyn (M'Coy). *Merionethshire.*—E. and W. of Bala Lake; N. of Bala; Corwen; N. of Tremadoc (M'Coy).
T. seticornis, His. -	Leth. Suec. Supp. t. 40, fig. 19.	*Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—N.E. and W. of Bala Lake. *Montgomeryshire.*—Llanwddyn.
T. radiatus, Murch. -	Siluria, pl. 4, fig. 8	*Merionethshire.*—N. of Tremadoc (M'Coy).
Harpes Doranni, Portl.	Portl. Geol. Rep., pl. 5, fig. 4.	*Denbighshire.*—S. of Llangollen.
Harpes, sp. - -	- - -	*Merionethshire.*—E. of Bala Lake.
PHYLLOPODA and OSTRACODA.		
Beyrichia complicata, Salter. Pl. 19, fig. 9.	- -	*Caernarvonshire.*—Carnedd Dafyd; Penmachno. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Llanfwrog, near Ruthin (M'Coy). *Montgomeryshire.* — Llangynnog; Llanwddyn. *Merionethshire.*—E. and W. of Bala Lake.
B. strangulata, Salter -	Pal. Foss., M'Coy, t. 1 E., fig. 1.	*Denbighshire.* — S. of Cerrig-y-Druidion.
Beyrichia, sp. - -	- - -	*Merionethshire.*—W. of Bala Lake.
Cythere? umbonata, Salter (*Ceratiocaris*, M'Coy).	Ib., fig. 6 - -	*Caernarvonshire.* — Conway Falls (M'Coy); Dolwyddelan. *Denbighshire.* — Dermydd fawr, under Craig Bronbanog (M'Coy); Llanfwrog, near Ruthin. *Montgomeryshire.* — Llanwddyn, Llanfyllin; Meifod. *Merionethshire.*—E. W., and S.E. of Bala Lake; N. of Bala.

Name.	Reference to other Works.	Locality.
HYDROZOA and POLYZOA.		
Diplograptus pristis, His. Pl. 11 A., fig. 1 *d. e.* Pl. 12, fig. 1.	- - -	*Merionethshire.*—N. of Bala Lake. *Caernarvonshire.* — Conway Falls (M'Coy). *Denbighshire.* — Glyn Ceiriog (M'Coy).
D. foliaceus, Murch. -	Siluria, pl. 1, fig. 2	*Merionethshire.*—Corwen (M'Coy); Pentre-cwm-ddu, S. of Glyn Diffwys.
Monograptus? priodon, Bronn.	Ib., pl. 12, fig. 1 -	*Denbighshire.* — Nantyr, in Glyn Ceiriog (M'Coy). *Montgomeryshire.*—Peniarth; Meifod (M'Coy).
M. sagittarius, Linn. Pl. 11 A., fig. 2.	- - -	*Merionethshire.*—N. of Tremadoc.
Leptograptus flacidus, Hall.	- - -	*Caernarvonshire.*—Conway.
Diplograptus quadrimucronatus, Hall.	- - -	*Do.* do.
D. truncatus, Lap. -	- - -	*Do.* do.
D. foliaceus, Murch. -	- - -	*Do.* do.
Corynoides calycularis, Nich.	- - -	*Do.* do.
Dicranograptus ramosus, Hall.	- - -	*Do.* do.
D. Nicholsoni, Hopk. -	- - -	*Do.* do.
Dicellograptus Forchhammeri, Gein.	- - -	*Do.* do.
D. Morrisi, Hopk. -	- - -	*Do.* do.
Fenestella subantiqua, D'Orb.	Siluria, pl. 41, fig. 16.	*Denbighshire.* — S.E. of Cerrig-y-Druidion.
F. Milleri, D'Orb. -	Siluria Foss. 49, fig. 4, p. 239.	*Denbighshire.*—S. of Glyn Ceiriog (M'Coy). *Merionethshire.* — Cerrig - cocdog, Corwen (M'Coy).
Fenestella, two species -	- - -	*Caernarvonshire.* — Carnedd Dafydd. *Merionethshire.*—S.E. of Bala Lake. *Montgomeryshire.*—Llanfyllin.
Phyllopora, two species, one with broad meshes.	- - -	*Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin.
P. Hisingeri (*Retepora*), M'Coy.	Pal. Foss., pl. 1 C., fig. 18.	*Denbighshire.*—Glyn Ceiriog, near Chirk; near Wrexham.
Ptilodictya dichotoma, Portl.	Portl. Geol. Rep., pl. 21, fig. 3.	*Montgomeryshire.* — Llanfyllin; Meifod. *Merionethshire.*—W. of Bala Lake.
P. costellata, M'Coy -	Pal. Foss. t. 1 C., fig. 15.	*Denbighshire.* — Glyn Ceiriog (M'Coy).
P. explanata, M'Coy -	Ib., t. 1 C., fig. 16	*Denbighshire.* — Near Llangollen; Glyn Ceiriog; Cyrn-y-brain; Wrexham (M'Coy). *Montgomeryshire.* — Llanfyllin (M'Coy).
P. fucoides, M'Coy -	Ib., fig. 14 -	*Merionethshire.*—E. of Bala Lake; Corwen (M'Coy).
P. acuta, Hall - -	Siluria Foss. 27, fig. 2.	*Denbighshire.*—Glyn Ceiriog; S. of Llangollen (M'Coy). *Montgomeryshire.* — Llechwedd-wyd; Llanfyllin (M'Coy).
Berenicea heterogyra, M'Coy.	Pal. Foss. 1 C., fig. 17.	*Merionethshire.*—W. of Bala Lake.

Name.	Reference to other Works.	Locality.
Glauconome disticha, Goldf.	Siluria, pl. 41, fig. 12.	*Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.*—Llanfyllin.
BRACHIPODA.		
Atrypa marginalis, Dalm.	Siluria, pl. 9, fig. 2	*Caernarvonshire.*—Yspytty Evan. *Denbighshire.*—Glyn Ceiriog. *Montgomeryshire.* — Llanfyllin ; Meifod; Llanwddyn. *Merionethshire.*—Bala.
Crania divaricata, M'Coy	Pal. Foss. t. 1 H., figs. 1, 2.	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Merionethshire.* — Pont-y-Glyn Diffwys; Corwen; Bala Lake.
Discina subrotunda, Portl.	Portl. Geol. Rep., pl. 32, fig. 10.	*Montgomeryshire.*—Llanfyllin.
Discina, sp. - -	- - -	*Caernarvonshire.* — Carnedd Dafydd. *Montgomeryshire.*—Llanfyllin.
Leptæna sericea, Sow. -	Siluria, pl. 5, fig. 14.	*Caernarvonshire.* — Carnedd Dafydd; Bettws-y-coed; Dolwyddelan; Llyn Idwal. *Denbighshire.* — S. of Cerrig-y-Druidion; S. of Llangollen; Cricor Mawr; E. of Llanelidan (M'Coy); S. of Pont-y-Glyn Diffwys. *Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin; N. of Llangedwin. *Merionethshire.*—E., W., and S.E. of Bala Lake; N. of Bala; *et passim.*
L. quinquecostata (*Orthis*), M'Coy.	Sil. Foss. Ireland, pl. 3, fig. 8.	*Merionethshire.*—W. of Bala Lake.
L. tenuicincta, M'Coy -	Pal. Foss. Woodw. Mus., pl. 1 H., fig. 40.	*Denbighshire.* — S. of Cerrig-y-Druidion. *Montgomeryshire.* — Llanfyllin; Meifod. *Merionethshire.*—W. and N. of Bala Lake, especially Rhiwlas.
L. scissa, MSS. -	A common species	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. and W. of Bala Lake.
L. transversalis, Dalm.	Siluria, 2nd ed., pl. 9, fig. 17.	*Denbighshire.*—Glyn Ceiriog. *Merionethshire.*—Bala, &c.
—— var. *undulata*, Salter (*Lept. quinquecostata*, M'Coy in part).	Pal. Foss., pl. 1 H., figs. 30, 31.	*Montgomeryshire.*—Allt-yr-Anker; Meifod; Llanfyllin.
Lingula ovata, M'Coy -	Pal. Foss. t. 1 L., fig. 6.	*Denbighshire.* — S. of Llangollen (*L. longissima*, M'Coy). *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—E. of Bala Lake; N. of Bala.
L. tenuigranulata, M'Coy	Siluria, p. 212, fig. 5.	*Montgomeryshire.* — Llanwddyn; Meifod.
Orthis Actoniæ, Sow. Pl. 21, figs. 1–8.	- - -	*Caernarvonshire.* — Bettws-y-coed, Penmachno. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Glyn Ceiriog. *Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin. *Merionethshire.*—E. and W. of Bala Lake; W. of Corwen.

Name.	Reference to other Works.	Locality.
O. biloba, Linn.	Siluria, pl. 9, fig. 20.	*Denbighshire.* — Glyn Ceiriog (M'Coy).
O. alternata, Sow. (*retrorsistria*, M'Coy). Pl. 19, figs. 11–13.	- - -	*Caernarvonshire.*—Penmachno. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Glyn Ceiriog; Pentre-cwm-dda; S. of Glyn-Diffwys. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn; N. of Llangedwyn; Llangynnog. *Merionethshire.*—E. and S.E. of Bala Lake; Pont-y-Glyn-Diffwys.
O. flabellulum, Sow. Pl. 21, figs. 9, 10.	- - -	*Caernarvonshire.* — Carnedd Dafydd; Llyn Idwal; Llyn Ogwen; Boduan, large and fine; Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Glyn Ceiriog. *Montgomeryshire.* — Llanwddyn; Meifod; N. of Llangedwin; Llanfyllin. *Merionethshire.*—E., W., and S.E. of Bala Lake; Llanrhaiadr; Snowdon.
O. Hirnantensis, M'Coy	Pal. Foss., pl. 1 H., fig. 11.	*Merionethshire.* — Aber Hirnant; Maes-y-fallen; and Cwm Æthnen, E. of Bala.
O. biforata, Schlotheim	Siluria, p. 211, fig. 1	*Caernarvonshire.*—Bettws-y-coed. *Denbighshire.* — S.E. of Cerrig-y-Druidion; S. of Llangollen. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn. *Merionethshire.*—W. of Bala Lake.
—— var. *fissicostata*, M'Coy.	Pal. Foss., p. 193 -	*Montgomeryshire.* — Meifod (M'Coy). *Merionethshire.*—Bala; Aber Hirnant (M'Coy).
O. calligramma, Dalm. Pl. 22.	- - -	*Caernarvonshire.*—Bettws-y-coed; Dolwyddelan; Yspytty Evan. *Denbighshire.*—S. of Llangollen; S.E. of Cerrig-y-Druidion. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn; Welshpool. *Merionethshire.*—E. of Bala Lake.
O. crispa, M'Coy	Pal. Foss., pl. 1 H., fig. 43.	*Caernarvonshire.*—Bettws-y-coed. *Montgomeryshire.* — Llanfyllin; Meifod.
O. elegantula, Dalm. (including *O. parva*, Pander and M'Coy).	Siluria, pl. 5, fig. 5	*Caernarvonshire.* — Llyn Idwal; Moel Siabod; Carnedd Dafydd; Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S. of Llangollen; S. and S.E. of Cerrig-y-Druidion; Llanfwrog, near Ruthin (M'Coy). *Montgomeryshire.*—N. of Llangedwyn; Meifod; Llanfyllin; Welshpool; Llanwddyn. *Merionethshire.*—S. of Llangollen; S. and S.E. of Cerrig-y-Druidion; Corwen; Llanrhaiadr; N. of Tremadoc (M'Coy).
O. insularis, Eichw.	Geol. Russ., 11, pl. 8, fig. 7.	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—Llanrhaiadr.

Name.	Reference to other Works.	Locality.
O. spiriferoides, M'Coy	Siluria, p. 211, fig. 2.	*Caernarvonshire.* — Dolwyddelan; Pwllheli; Penmachno. *Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.* — Llanwddyn; Meifod; Llanfyllin; Welshpool. *Merionethshire.*—E., W., and S.E. of Bala Lake; Dinas Mowddwy; Llanrhaiadr.
O. porcata, M'Coy. Pl. 19, fig. 14.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Denbighshire.*—S. of Llangollen; Cyrn-y-brain, Wrexham; Glyn-Ceiriog. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn; Welshpool. *Merionethshire.*—Near Corwen.
O. sagittifera, M'Coy -	Pal. Foss. Woodw. Mus., pl. 1 H., figs. 15–19.	*Merionethshire.*—Aber Hirnant; E. of Bala.
O. simplex, M'Coy -	Sil. Foss., Ireland, pl. 3, fig. 18.	*Merionethshire.*—W. of Bala Lake.
O. testudinaria, Dalm. -	Siluria, pl. 5, figs. 1, 2.	*Caernarvonshire.*—Bettws-y-coed; Boduan; Penmachno. *Denbighshire.*—S. of Llangollen. *Montgomeryshire.* — Llanfyllin; Meifod; Gaer-fawr; Welshpool. *Merionethshire.*—E. of Bala Lake.
O. turgida, M'Coy -	Pal. Foss., Woodw. Mus., pl. 1 H., figs. 21, 24.	*Caernarvonshire.* — Dolwyddelan; Conway Falls; Bettws-y-coed. *Denbighshire.*—Cerrig-y-Druidion. *Montgomeryshire.*—Llanfair.
O. vespertilio, Sow. -	Siluria, pl. 6, fig. 13	*Caernarvonshire.* — Dolwyddelan; Penmachno. *Denbighshire.*—S. of Llangollen; S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—Meifod; Welshpool; N. of Llangedwyn; Llanwddyn; Llanfyllin. *Merionethshire.*—E., W., and S.E. of Bala Lake; near Corwen; Hirnant Ridge.
O., sp. like *elegantula* -	- - -	*Montgomeryshire.*—Llanfyllin.
Orthisina ascendens, Pander.	Pander, t. 17, fig. 6	*Denbighshire.* — Cyrn - y - brain, Wrexham. *Merionethshire.*—Corwen (M'Coy).
Rhynchonella, sp. (somewhat like *R. serrata*, M'Coy), Siluria, p. 230, fig. 1.	- - -	*Caernarvonshire.*—E. of Y-Tryfan; Llyn Idwal; Carnedd Dafydd (abundant, Salter).
R. depressa, Sow. -	Siluria, pl. 22, fig. 17.	*Merionethshire.* — Brynbedwog; Bala (M'Coy).
R. (like *R. capax*, Hall)	- - -	*Merionethshire.*—W. of Bala Lake; Cymmerig; E. of Bala.
R., n. sp. - -	- - -	*Caernarvonshire.* — Carnedd Dafydd.
R., small plaited sp. -	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion.
Siphonotreta micula, M'Coy.	Pal. Foss., Woodw. Mus., pl. 1 H., fig. 3.	*Merionethshire.*—N. of Bala; near Glyn Diffwys (M'Coy).
Spirifera trapezoidalis, Dalm.	Siluria, pl. 9, fig. 24.	*Merionethshire.*—W. of Bala Lake.
Strophomena alternata, Conrad.	Pal. N. York, p. 102.	*Montgomeryshire.*—Llanfyllin.

Name.	Reference to other Works.	Locality.
S. antiquata, Sow. -	Siluria, pl. 20, fig. 18.	*Montgomeryshire.*—Llanfyllin.
S. depressa, Dalm. -	Siluria, pl. 20, fig. 20.	*Caernarvonshire.* — Carnedd Dafydd; Llyn Idwal; Snowdon, &c.; Bettws-y-coed. *Denbighshire.* — S.E. of Cerrig-y-Druidion; S. of Llangollen. *Montgomeryshire.* — Llanfyllin; Llanwddyn; Meifod. *Merionethshire.* — E., W., and S.E. of Bala Lake, *et passim.*
S. deltoidea, Hall -	Hall, Pal. N. Y., vol. 1, t. 31A, f. 3.	*Denbighshire.*—Cerrig-y-Druidion; Cyrn-y-brain. *Merionethshire.*—Bala. *Montgomeryshire.*—Meifod (all the above localities from M'Coy).
S. expansa, Sow. -	Siluria, pl. 6, fig. 4	*Caernarvonshire.* — Carnedd Dafydd; Bettws-y-coed; Dolwyddelan; Pwllheli. *Denbighshire.*—S.E. of Cerrig-y-Druidion; Llangollen. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn; Cader Dinmael. *Merionethshire.* — E., W., and S.E. of Bala Lake; Llanrhaiadr.
S. grandis, Sow. -	Ib., figs. 6, 7 -	*Caernarvonshire.* — Dolwyddelan; Boduan. *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—Bala.
S. tenuistriata, Sow. -	Ib., pl. 15, fig. 4 -	*Caernarvonshire.* — Bettws-y-coed; Dolwyddelan. *Denbighshire.* — S.E. of Cerrig-y-Druidion; Cyrn-y-brain; S. of Llangollen. *Montgomeryshire.* — Llanfyllin; Meifod; Llanwddyn; Welshpool. *Merionethshire.*—N. and E. of Bala Lake.
S. simulans, M'Coy -	Pal. Foss., t. 1 H., figs. 33–35.	*Denbighshire.*—Glyn Ceiriog; Llangollen. *Montgomeryshire.*—Gaer-fawr, &c. (M'Coy).
S. Pecten, Linn. -	Siluria, p. 251, foss. 58, fig. 3.	*Denbighshire.*—Glyn Ceiriog; Llangollen (M'Coy).
LAMELLIBRANCHIATA.		
Ctenodonta obliqua, Portl.	Siluria, p. 218, fig. 6.	*Merionethshire.*—W. of Bala Lake.
C. lævis, Sow. - -	Ib., pl. 7, fig. 3 -	*Caernarvonshire.*—Bettws-y-coed; Dolwyddelan.
C. varicosa, Salt. Woodcut 13, f. 1.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Montgomeryshire.*—Llanwddyn. *Merionethshire.*—E. and W. of Bala Lake; N. of Bala.
C., sp. - - -	- - -	*Caernarvonshire.* — Carnedd Dafydd; Dolwyddelan. *Montgomeryshire.* — Llanwddyn; Llanfyllin.
C. Edmondiiformis (*Arca*, M'Coy).	Pal. Foss., pl. 1 K., fig. 2.	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—Bala; Aber Hirnant (from M'Coy).

Name.	Reference to other Works.	Locality.
Cucullella, sp. - -	- - -	*Caernarvonshire.* — Bettws-y-coed; Dolydd Ceiriog Waterfall, in the Berwyn Mountains.
New genus allied to *Ctenodonta.*	- - -	*Montgomeryshire.*—Meifod.
Modiolopsis obliqua, Sow.	Siluria, pl. 7, fig. 2	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. of Bala Lake.
M., sp. like *M. Nilssoni*	Hisinger - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—E. and W. of Bala Lake.
M., 4 sp. - -	- - -	*Caernarvonshire.* — Carnedd Daffydd; Bettws-y-coed. *Denbighshire.*—Cerrig-y-Druidion. *Merionethshire.*—N. of Bala.
Pterinea pleuroptera, M'Coy.	Pal. Foss., pl. 1 I., fig. 12.	*Denbighshire.* — Cyrn - y - brain (M'Coy).
P. lineata, M'Coy -	Ib., p. 261 -	*Montgomeryshire.* — Moel Uchlas (M'Coy).
P., other species of -	- - -	*Montgomeryshire.*—Llanfyllin, &c. *Merionethshire.*—W. of Bala Lake, &c.
Orthonota (*O. verisimilis*, MSS.), a large Solen-like species.	Not yet figured -	*Montgomeryshire.*—Allt-y-gader, Llanfyllin (Mr. Prosser's collection).
O. postlineata, M'Coy -	Pal. Foss., pl. 1 I., fig. 22.	*Merionethshire.*—E. of Bala Lake.
O., various sp. - -	- - -	*Caernarvonshire.*—Dolwyddelan. *Montgomeryshire.*—Llanfyllin. *Merionethshire.*—N. of Bala.
Palæarca bulla, Salter. Woodcut 13, fig. 3.	- - -	*Montgomeryshire.*—Meifod (also at Horderley, Shropshire).
P. obscura, id. Woodcut 13, fig. 2.	- - -	*Montgomeryshire.*—Meifod.
P. modiolaris, id. Woodcut 12, fig. 1.	- - -	*Merionethshire.*—Bala.
P., sp. Woodcut 12, fig. 2	- - -	*Do.* do.
P. quadrata, id. Woodcut 12, fig. 3.	- - -	*Do.* Bettws-y-coed.
P. Billingsii, id. Woodcut 12, fig. 4.	- - -	*Montgomeryshire.*
GASTEROPODA.		
Cyclonema crebristria, M'Coy. Woodcut 14, fig. 5.	- - -	*Caernarvonshire.* — Carnedd Daffydd. *Montgomeryshire.* — Llanfyllin; Meifod. *Merionethshire.* — E. and S.E. of Bala Lake; N. of Bala.
C., sp. - - -	- - -	*Montgomeryshire.*—Llanfyllin.
Holopea concinna, M'Coy	Siluria, p. 215, fig. 5.	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Merionethshire.*—N. of Bala.
H. striatella, Sow. -	Ib., pl. 7, fig. 4 -	*Merionethshire.*—W. of Bala Lake.
H., sp. - - -	- - -	*Caernarvonshire.*—Bettws-y-coed.
H. lymnæoides, Forbes. Woodcut 14, fig. 3.	- - -	*Merionethshire.*—Rhiwlas.
H. exserta, id. Woodcut 14, fig. 1.	- - -	*Merionethshire.*—W. of Bala Lake.
H. carinata, id. Woodcut 14, fig. 4.	- - -	*Do.* do.
H. conica, id. Woodcut 14, fig. 2.	- - -	*Do.* do.

Name.	Reference to other Works.	Locality.
Holopella conica, Sow. ? or an allied sp.	Siluria, pl. 34, fig. 10.	*Merionethshire.*—W. of Bala Lake.
Murchisonia angulata, Sow.	Siluria, pl. 10, fig. 12.	*Caernarvonshire.* — Carnedd Daf-ydd.
M. gyrogonia, M'Coy -	Pal. Foss., t. 1 K., fig. 43.	*Caernarvonshire.*—Yspytty Evan. *Montgomeryshire.*—N. of Llanged-win; Llanfechan (M'Coy).
M. scalaris, Salter -	Quart. Geol. Journ., vol. 5, tab. 1, f. 2.	*Caernarvonshire.* — Carnedd Daf-ydd; Llyn Idwal.
M. simplex, M'Coy -	Pal. Foss., pl. 1 L., fig. 21.	*Caernarvonshire.* — Bettws-y-coed; Moel Siabod. *Denbighshire.* — S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—N. of Llanged-wyn; Llanwddyn; Meifod. *Merionethshire.*—W. of Bala Lake.
M. cancellatula, M'Coy	Pal. Foss., t. 1 L., fig. 20.	*Montgomeryshire.* — Allt-yr-Anker, Meifod (M'Coy).
M. pulchra, M'Coy -	Sil. Foss., Ireland, pl. 1, fig. 19.	*Montgomeryshire.* — Allt-yr-Anker, Meifod (M'Coy). *Merionethshire.*—N. of Tremadoc (M'Coy).
M. turrita, Portl. ? -	Geol. Rep., pl. 30, fig. 7.	*Merionethshire.*—Bala (M'Coy).
M., sp. - - -	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—W. of Bala Lake.
Euomphalus, sp. -	- - -	*Merionethshire.*—W. of Bala Lake.
Raphistoma lenticularis, Sow. ?	Siluria, pl. 10, fig. 10.	*Caernarvonshire.* — Carnedd Daf-ydd; Llyn Idwal. *Montgomeryshire.*—Meifod.
R. æqualis, Salt. (*Euompn. qualteriatus*, id. *olim.*).	Ib., p. 215, fig. 2 -	*Montgomeryshire.*—Llanfyllin. *Merionethshire.*—W. of Bala Lake.
R., 2 species - -	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—W. of Bala Lake. *Denbighshire.*—S. of Llangollen.
Trochonema, large sp. -	- - -	*Denbighshire.*—S. of Llangollen.
PTEROPODA.		
Theca triangularis, Portl.	Siluria, p. 218, fig. 2.	*Denbighshire.* — S. of Cerrig-y-Druidion.
—— *reversa*, Salter. Woodcut 14, fig. 6.	- - -	*Merionethshire.*—W. of Bala Lake.
HETEROPODA.		
Bellerophon bilobatus, Sow.	Siluria, pl. 7, fig. 7	*Caernarvonshire.* — Bettws-y-coed; Dolwyddelan; Yspytty Evan. *Denbighshire.*—S. of Llangollen. *Montgomeryshire.* — Llangedwyn; Meifod. *Merionethshire.*—Dinas Mowddwy; E. and W. of Bala Lake.
B. perturbatas, Sow. Woodcut 16.	- - -	*Caernarvonshire.* — Carnedd Daf-ydd.
B. carinatus, Sow. -	Siluria, pl. 34, fig. 8	*Denbighshire.* — S.E. of Cerrig-y-Druidion. *Montgomeryshire.*—N. of Llanged-wyn; E. of the Berwyns *Caernarvonshire.*—Twll-du, at the head of Llyn Idwall.
B. dilatatus, Sow. -	Ib., pl. 25, figs. 5, 6	*Denbighshire.* — S.E. of Cerrig-y-Druidion.

Name.	Reference to other Works.	Locality.
B. nodosus, Salt. Wood-cut, fig. 15.	- - -	*Caernarvonshire.* — Llyn Idwal; Dolwyddelan. *Denbighshire.*—Teirw River, S. of Llangollen. *Montgomeryshire.* — Llanwddyn; Llangedwyn. *Merionethshire.*—E. and W. of Bala Lake; N. of Bala.
CEPHALOPODA.		
Cyrtoceras inæquiseptum, Portl.	Siluria, p. 220, fig. 1.	*Denbighshire.*—S. of Llangollen.
C. sonax, n. sp. Pl. 25, fig. 1.	- - -	*Merionethshire.*—Rhiwlas.
C. atramentarium, n. sp. Pl. 25, figs. 2–4.	- - -	*Merionethshire.*—W. of Bala Lake.
C., other species -	- - -	*Caernarvonshire.* — Carnedd Dafydd. *Merionethshire.*—Rhiwlas.
Lituites (*Trocholites*) *anguiformis*, Salt.	Pal. Foss., App., p. 8, pl. 1 L., fig. 26.	*Denbighshire.*—S. of Llangollen.
L. cornu-arietis, Sow. -	Silurian, pl. 7. fig. 10.	*Merionethshire.*—W. of Bala Lake.
L. cornu-arietis, var. -	- - -	*Denbighshire.* — S. of Cerrig-y-Druidion (also in Tyrone).
L. planorbiformis, Conrad. Pl. 25, fig. 5.	- - -	*Caernarvonshire.*—Bettws-y-coed.
L., 2 other species, one with oblique waved septa.	- - -	*Merionethshire.*—Rhiwlas.
Orthoceras Ibex, Sow. -	Siluria, pl. 29, fig. 3.	*Merionethshire.*—W. of Bala Lake.
O. vagans, Salt. Pl. 24, figs. 1–5.	- - -	*Caernarvonshire.*—Bettws-y-coed. *Merionethshire.*—N. and W. of Bala Lake.
O. audax, n. sp. Pl. 24, fig. 7.	- - -	*Caernarvonshire.*—Moel Siabod. *Merionethshire.*—W. of Bala Lake.
O., sp. Pl. 24, fig. 6 -	- - -	*Do.* do.
O., smooth species -	- - -	*Caernarvonshire.*—Dolwyddelan. *Denbighshire.* — S. of Cerrig-y-Druidion. *Merionethshire.*—W. of Bala Lake; Rhiwlas, &c.
O., nearly smooth sp., but with fine longitudinal striæ.	- - -	*Merionethshire.*—W. of Bala Lake.

The following table embraces the distribution of all the known species in the Caradoc Rocks, and their relation to the formations below and above; also showing those species at present known to be confined to the Caradoc. Their exact localities are given on pp. 392–405. This with other tables through the Appendix, prepared to show the history of the Cambrian and Silurian species in North and South Wales, will much facilitate and further the history and aid in understanding the physical structure of the intricate region described throughout this memoir.

Distribution of Species in the Caradoc Rocks of England, Wales, and Scotland.

Classes.	Pass from		Caradoc or Bala Species.*	North Wales.				South Wales.		England.				Pass to				
	Arenig.	Llandeilo.		Caernarvonshire.	Denbighshire.	Montgomeryshire.	Merionethshire.	Pembrokeshire.	Carmarthenshire.	Shropshire.	Westmoreland.	Scotland.	Ireland.	Lower Llandovery.	Upper Llandovery.	Woolhope.	Wenlock.	Ludlow.
Protozoa			*Ischadites tessellatus*, Salt.	—	—					—	—	?						
			Cliona (Vioa) prisca, M'Coy.															
			C. antiqua, Port.															
			Stromatopora striatella, D'Orb.	—										×		×	×	×
			Saccamina, sp.															
			Sphærospongia hospitalis, Salt.															
			Acanthospongia Silurien-sis, M'Coy.											×				
		×	*Nidulites favus*, Salt.											×				
			Astylospongia grata, Salt.															
			Girvanella problematica, Nich.															
			Hyalonema ? Girvanse, N. & E.															
Actinozoa			*Syringophyllum organum* (*Sarcinula*), Linn.															?
			Favosites aspera, D'Orb.	—	—	—	—	—	—					×	×	×	×	×
			F. Girvanensis, N. & E.												?			
			F. gothlandica, *R.*, Linn.		—					—	—			×	×	×	×	
			F. crassa, M'Coy															
			F. cristata, *S.*, Blum.												×		×	×
			F. multipora, Lonsd.					—						×	×		×	
		×	*F. fibrosus*, Goldf.	—	—	—	—	—	—	—	—			×	×	×	×	×
			F. Lycoperdon, Hall	—	—	—	—							×				
			Heliolites interstinctus, Linn.		—	—		—	—					×	×	×	×	×
			H. parasitica, N. & E.															
			H. favosus, M'Coy (*Lyopora*).											×	×			
			H. megastoma, M'Coy		—	—	—				—			×	×		×	
			H. tubulatus, Lons.			—		—			—			×	×	×	×	×
			H. inordinata, Lonsd.					—										
			Pætraia bina, Lonsd.					—	—	—	—			×	×		×	
			P. uniserialis, M'Coy		—	—								×	×			
			P. crenatula					—										
			P. rugosa, Phill.		—	—					—			×	×			
			P. sub-duplicata, M'Coy		—			—	—		—			×	×	×	×	
			P. elongata, Phill.	—			—	—	—		—			×	×		×	
		×	*Halysites catenularis*, Linn.		—	—		—	—		—			×	×		×	×
			Plasmopora patelliformis, Lonsd.						—		—			×	×		×	
			Stylaræa occidentalis, N. & E.															
			Omphyma turbinata, Linn.		—					?	—			×	×	×	×	×
			Thecostegites scoticus, N. & E.															
			Aulopora		—													
			Alveolites repens, Forsyt.							—							×	
			Aulacophyllum mitratum, His.	—	—			—			—			×	?		×	
			Calostylis Lindströmi, N. & E.															
			Cyathophyllum articu-latum, Wahl.							—				×			×	
			Fistulipora favosa, N. & E.															
			F. pilula, N. & E.															
			Streptelasma aggregatum, N. & E.															
			S. craigense, M'Coy															
			Monticulipora explanata, M'Coy.									?		×				
			M. lens, M'Coy	—	—	—	—			—	—							

* All the special Scotch or Irish species are not noticed here, not having comparison with either N. or S. Welsh species, nevertheless most are given.

Classes.	Pass from: Arenig.	Pass from: Llandeilo.	Caradoc or Bala Species.	North Wales: Caernarvonshire.	North Wales: Denbighshire.	North Wales: Montgomeryshire.	North Wales: Merionethshire.	South Wales: Pembrokeshire.	South Wales: Carmarthenshire.	England: Shropshire.	England: Westmoreland.	Scotland.	Ireland.	Pass to: Lower Llandovery.	Pass to: Upper Llandovery.	Pass to: Woolhope.	Pass to: Wenlock.	Pass to: Ludlow.
Actinozoa—cont.		×	*M. favulosa*, Phill.	—	—	—	—			—	—							
			M. petropolitana, Pand.	—	—	—	—	—		—								
			Tetradium Peachii, N. & E.									—						
			Prasmopora grayæ, N. & E.									—						
			Syringophyllum organum, Linn.								—							
Annelida			*Tentaculites anglicus*, Salt.	—	—	—	—	—	—	—	—	—	—	×	×		×	×
			T. annulatus, Schloth.	—							—	—						
			Cornulites serpularius, Schloth.	—	—			—	—	—		—	—	×	×	×	×	×
		×	*Serpulites dispar*, Salt.							—							×	×
			S. longissimus, Murch.									—					×	×
			Myrianites McLeayi, Murch.						—									
			M. tenuis, M'Coy									—						
			Crossopodia scotica, M'Coy									—						
			Lumbricaria antiqua, Portl.										—					
			L. gregaria, Portl.										—					
			Scolecoderma, sp.				—											
			Scolites	—	—	—	—											
			Trachyderma lævis, M'Coy							—			—					
			Nemertites ollivanti, Murch.					—										
		×	*Nereites Cambrensis*, Murch.					—	—			—						
			N. Sedgwickii, Murch.				—					—						
			Conchicolites gregarius, Nich.								—							
Echinoder-mata.			*Sphæronites Litchii*, Forbes.				—	—										
			S. munitus, Forbes				—	—										
			S. pyriformis, Forbes				—	—										
			S. punctatus, Forbes				—	—			—							
			S. stelluliferus, Salt.				—	—										
			S., sp.				—	—										
			Echinosphærites balthicus, Eichw.	—	—	—	—	—	—	—	—		—					
			E. (caryocistites) Davisii, M'Coy.	—	—		—				—							
		×	*E. granulatus*, M'Coy				—	—					—					
			E. granatum, Wahl.				—	—					—					
			E. aurantium, Gyll.				—	—										
			E. arachnoideus, Forbes					—						×				
			Glyptocystites, sp.		—			—						×				
			Hemicosmites squamosus, Forbes.			—	—											
			H. pyriformis, V. Buch.				—											
			H. oblongus, Pand.		—			—										
			H. rugatus, Forbes			—	—	—			?		—					
			Pleurocystites Rugeri, Salt.					—	—	—								
			P., sp.				—											
			Cyclocystoides Marstoni, Salt.							—								
			C. caractaci? Salt.							—								
			Agelacrinites Buchianus, Forbes.	—														
		×	*Glyptocrinus basalis*, M'Coy.	—		—	—		—	—								
			G. lævis, Portl.										—					
			Hterocrinus, sp.			—												
			Palæaster asperimus, Salt.			—												
			P. caractaci, Salt.								—							
			P. obtusus, Forbes				—											
			P. imbricatus, Salt.			—												
			Edrioaster Buchii, Forbes	—														
			Protaster Salteri, Forbes		—													
			Atelocystites oblongus					—										
			Tetraster Wyville Thomsoni, E. & N.									—						
			Myelodactylus, sp.									—						

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Crustacea			*Acidaspis Brightii*, Murch.					—	—			—		×	×		×	
			A. hystrix, Thom.									—						
		×	*A. Jamesii*, Salt.									—	—					
			A. lalage, Thom.									—						
			A. bispinosa, M'Coy									—						
			A. calliparaos, Thom.									—						
			A. caractaci, Salt.							—								
			A. parvulus, Forbes							—								
		×	*Ampyx nudus*, Murch.			—			—									
			A. tumidus, Forbes			—	—	—		—	—							
			A. nasutus									—						
		×	*A. mammilatus*, Sars.				—					—						
			A. pennatus, Salt.							—								
		×	*A. rostratus*, Sars.									—	—	?	?			
			A. Macallumi, Salt.									—						
			A. Macconochiei, Eth.									—						
			A. Hornei, Eth.									—						
			Agnostus trinodus, Salt.		—		—	—		—	—	—						
			A. perrugatus, Bar.									—						
			A. limbatus, Salt.									—						
		×	*Asaphus Powisii*, Murch.	—	—	—	—		—	—	—	—						
			A. radiatus, Salt.		—	—						—						
			A. gigas, De Kay									—						
			A. Marstoni, Salt.							—								
			A. nobilis, Barr.									—						
			A. rectifrons, Port.										—					
			A. scutalis, Salt.								—		—					
			Amphion benevolens, Salt.										—					
			A. pauper, Salt.										—					
			A. pseudoarticulatus, Portl.									—	—					
			Bronteus hibernicus, Portl.										—					
			B. Andersoni, Eth.									—			×			
			B. Brongniarti, Barr.									—						
			Bronteopsis scotica, Salt.									—						
		×	*Calymene Blumenbachii*, Brong.	—	—	—	—	—	—	—	—	—	—	×	×	^	×	×
			C., var. *sub-diademata*, M'Coy.	—							—	—						
		×	*C. brevicapitata*, Portl.	—	—	—	—			—	—	—	—	×	×	×	×	
			C., var. *caractaci*, Salt.	—	—		—			—	—	—	—	×				
			C. alportiana, Salt.									—	—	×	×	×	×	×
		×	*C. duplicata*, Murch.							—								
			C. obtusa, M'Coy										—					
			C. arenosa, M'Coy										—					
			Cyclopyge rediviva, Barr.										—					
			C. armata, Barr.										—					
			Cheirurus bimucronatus, Murch.	—	—	—	—	—			—	—	—	×	×	×	×	×
			C. clavifrons, Dalm.		—	—	—	—				—	—	×				?
			C. juvenis, Salt.		—	—	—	—				—	—					
			C. octolobatus, M'Coy		—	—	—	—				—	—					
			C. cancrurus, Salt.										—					
			C. gelasinosus, Portl.									—	—					
			Cyphoniscus socialis, Salt.										—					
			Dionide Lapworthi, E. & N.										-					
		×	*Æglina mirabilis*, Forbes										—					
			Encrinurus multiscgmentatus, Portl.						—			—	—					
			E. sexcostatus, Salt.			—	—	—		—			—					
			E. punctatus, Brünn	—						—			—	×	×	×	×	×
			Cyphaspis megalops, M'Coy							—			—	×	×		×	×
			Barrandia Portlocki, Salt.										—					
			Cybele rugosa, Portl.	—	—	—	—	—	—		—	—	—					
			C. verrucosa, Dalm.	—	—	—	—	—	—	—	—	—	—	×				
	×	×	*Homalonotus bisulcatus*, Salt.	—	—	—	—			—	—	—	—					
			H. rudis, Salt.		—					—			—					
			H. Edgellii, Salt.							—			—					
			H. Sedgwickii, Salt.									—	—					
			Illænus Bailyi, Salt.										—					
			I. ocularis, Salt.										—					
			I. Macullumi, Salt.										—					
			I. Lewisii, Salt.							—			—					
		×	*I. quadrato-caudatus*, Portl.										—					

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Crustacea—*cont.*		×	*I. Murchisonii*, Salt.		—				—					×				
			I. Portlockii, Salt.															
		×	*I. Rosenbergii*, Eichw.											×				
		×	*I. Bowmanii*, Salt.	—										×	×			
			I. æmulus, Salt.															
			I. Thomsoni. Salt.											×				
			I. nexilis, Salt.												×			
			I. Davisii, Salt.							—								
			Primitia M'Coyii, Salt.															
			P. bicornis, Jones							—								
			P. Sancti Patrici, Jones															
			Lichas hibernicus, Portl.															
			L. laciniatus, Dalm.															
			L. nodulosus, Salt.				—											
			L. obscurus, Portl.															
			L. bulbiceps, Salt.															
			L. avus, Barr.[1]															
			L. laxatus, M'Coy	—	—	—	—	—	—	—	—			×	×			
			Tiresias insculptus, M'Coy															
			Phacops amphora, Salt.						—									
			P. Baylyi, Salt.															
			P. caudatus?, Brün.					—							×	×	×	×
			P. Dalmanii, Portl.															
			P. mucronatus, Brong.				—				—							
			P. Jamesii, Portl.															
			P. Jukesii, Salt.				—											
			P. oblusicaudatus, Salt.								—				?			
		×	*P. alifrons*, Salt.	—	—	—	—			—								
		×	*P. apiculatus*, Salt.	—	—	—	—			—	—							
			P. conicopthalmus, Bœck.	—	—	—	—		—	—	—							
			P. macroura, Sjœrer		—	—	—	—	—	—	—							
			P. Brongniarti, Portl.				—	—						×				
		×	*P. truncato caudatus*, Portl.							—								
			Remopleurides dorsospinifer, Portl.		—													
			R. laterispinifer, Portl.															
			R. Barrandei, Eth.															
			R. obtusus, Salt.															
			R. platiceps, M'Coy															
			R. radians, Barr.															
			R. longicostatus, Portl.				—	?		—								
			R. Colbii, Portl.				—			—								
			Staurocephalus Maclareni, Thom.												×			
			S. Murchisoni, Barr.				—		—	—	—				?	×		
			S. globiceps. Portl.															
			S. unicus, Thom.															
			Sphærexochus boops, Salt.					—			—							
			S. mirus, Beyr.													×	×	
			Salteria primæva, Thom.															
		×	*Trinucleus fimbriatus*, Murch.				—				—							
			T. thersites, Salt.															
		×	*T. concentricus*, Eaton	—	—	—	—	—	—	—	—				×			
			T. seticornis, His.		—	—	—	—	—	—	—							
			T. radiatus, Murch.	—		—	—											
			Stygina latifrons, Portl.		—		—											
			Harpes Dorani, Port.		—						—							
			H. Flanaganii, Port.															
			H. parvulus, M'Coy															
			Beyrichia Klædeni, M'Coy				—							×	×		×	×
			B. Wilckensiana, Jones								—							×
			B. affinis, Jones															
		×	*B. complicata*, Salt.	—	—	—	—	—	—	—	—							
			B. (Primitia) strangulata, Salt.		—		—				—							
			B. impendens, Jones								—							
			B. comma, Jones															
			Leperditia complicata	—	—	—	—		—	—	—							
			L. umbonata, Salt.	—	—	—	—	—										
			Bairdia Griffithiana, Jones.															
			B. murchisoniana, Jones															
			B. Salteriana, Jones															

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Crustacea—*cont.*			*Cythere aldensis*, M'Coy															
			C. Grayana, Jones															
			C. Bailyana, Jones															
			C. Jukesiana, Jones															
			C. Harknessiana, Jones															
			C. Wrightiana, Jones															
			Solenocaris solenoides, Young.															
			Pinnocaris Lapworthi, Eth.															
			Primitia Barrandiana, Jones.															
			P. semicircularis, Jones															
			P. protenta, Jones															
			Entomis globulosa, Jones															
			Turrilepas Peachii, E. & N.															
			Turrilepas Scotica, Eth.															
Hydrozoa*		×	*Diplograptus vesiculosus*, Nich.															
	×	×	*D. quadrimucronatus*, Hall	—														
			D. truncatus, Lapw.	—														
			D. palmæus, Barr.															
		×	*D. angustifolius*, Hall						—									
		×	*D. foliaceus*, Murch.	—			—	—	—	—								
			Idiograptus margaritatus, Bronn.	—												—		
			Leptograptus placidus, Hall.	—														
		×	*Climacograptus scalaris*															
			C. teretiusculus															
			C. bicornis, Hall	—					—									
			C. caudatus, Lapw.															
			Cyrtograptus hamatus															
			C. tricornis, Carr.															
			C. schæferi, Lapw.															
		×	*Dicellograptus Forchammeri*, Gein.	—					—									
			D. Morrisi, Hop.	—														
		×	*Dicranograptus ramosus*	—					—									
			D. scharenbergi, Lapw.															
			D. clingani, Carr.	—														
			D. rectus, Hop.															
			D. Nicholsoni, Hop.	—														
			Dictyonema elegans, Hop.															
			D. gracilis															
		×	*Monograptus convolutus*															
			Glossograptus Hincksii															
			Monograptus sagittarius, Linn.		?	—												
			Intricaria obscura															
		×	*Protovirgularia dichotoma*															
		×	*Rastrites peregrinus*, Barr.															
			Lasiograptus Harknessii, Nich.															
			L. margaritatus															
			Retiolites perlatus, Nich.															
			R. geinitzianus				—											
			R. fibratus, Lapw.															

* The entire and remarkable series of Graptolites occurring in the Hartfell beds of the Moffat series (Scotland) are necessarily not embodied here, most of them not occurring in Wales. Mr. Lapworth, in his able paper, discusses the whole question as to age and species, *vide* Quart. Geol. Soc., vol. xxxiv., pp. 240-346; also A. M. N. Hist., vol. iv., 1879, pp. 423-25, where the Girvan, Glenkiln, or Lower Moffat species are carefully catalogued; also those Irish species not occurring in the N. Welsh area; about 60 Scotch and Irish species are named; many Irish species also are not referred to here being local or not in N. Wales, but occur in Scotland. About 30 more Scotch species than are named in this table are given by Mr. Lapworth in his paper upon the Moffat series (loc. cit.); also A. M. N. Hist., ser. v., vol. iii., they illustrate 10 or more genera; not being Welsh species they are not really admissible here. R.E.

Classes.	Pass from Arenig.	Pass from Llandeilo.	Caradoc or Bala Species.	North Wales. Caernarvonshire.	Denbighshire.	Montgomeryshire.	Merionethshire.	South Wales. Pembrokeshire.	Carmarthenshire.	Eng. land. Shropshire.	Westmoreland.	Scotland.	Ireland.	Pass to Lower Llandovery.	Upper Llandovery.	Woolhope.	Wenlock.	Ludlow.
Bryozoa			*Retepora ramosa?*, His.															
			Fenestella sub-antiqua, D'Orb.											×	×	×	×	
			F. capillaris, Portl.															
			F. Milleri, Lonsd.												×			
			F. regularis, Portl.															
			F., sp.															
			F., sp.															
			Phyllopora, sp.															
			P., sp.															
			P. Hisingeri, M'Coy															
			Ptylodictya dichotoma, Portl.											×	×			
			P. costellata, M'Coy											×				
			P. explanata, M'Coy												×			
			P. fucoides, M'Coy															
			P. lanceolata, Goldf.											×	×	×	×	×
			P. acuta, Hall												×			
			Berenicea heterogyra, M'Coy.															
			Glauconome disticha, Goldf.															
Brachiopoda			*Atrypa marginalis*, Dalm.											×	×	×	×	
			A. reticularis, Linn.															
			A. apiculata, Salt.															
			A. imbricata, Sow.											×	×	×	×	
		×	*Crania divaricata*, M'Coy															
			Discina oblongata, Portl.															
		×	*D. crassa*, Hall															
			D. oblongata, Portl.															
			D. perrugata, M'Coy												×			
			D. Siulriana, Dav.															
			D. (Trematis) punctata															
			D. coronata, Salt.															
			Obolus Davidsoni, Salt.															
		×	*Leptæna sericea*, Sow.											×	×		×	
			L. lævissima, M'Coy															
		×	*L. quinquecostata*, M'Coy											×	×			
		×	*L. tenuicincta*, M'Coy															
			Chonetes lævigata, Sow.												×		×	
		×	*L. tenuissimestriata*, M'Coy															
			L. scissa, Salt.											×	×			
			L. Youngiana, Dav.															
			L. transversalis, Wahl.											×	×	×	×	×
		×	*Lingula attenuata*, Sow.															
		×	*L. brevis*, Portl.															
		×	*L. curta?*, Conrad.															
		×	*L. granulata*, Phill.															
			L. ovata, M'Coy															
			L. tenuigranulata, M'Coy															
			Merista cymbula, Dav.															
			Meristella angustifrons											×	×			
			M. tumida, Dalm.															
			M. crassa, Sow.											×	×			
		×	*Orthis Actonia*, Sow.											×				
			O. biloba, Linn.											×	×	×	×	×
			O. alternata, Sow.															
			O. flabellulum, Sow.															
			O. Hirnantensis, M'Coy															
		×	*O. biforata*, Schloth.											×	×	×	×	
		×	*O. confinis*, Salt.											×				
		×	*O. calligramma*, Dalm.											×	×	×	×	
			O., var. *calliptycha*, M'Coy															
			O., var. *plicata*, Sow.															
			O., var. *simplex*, M'Coy															
			O. porcata, M'Coy															
			O., var. *virgata*, Sow.															
			O. crispa, M'Coy											×				
		×	*O. elegantula*, Dalm.											×	×	×	×	×
		×	*O. insularis*, Eichw.											×	×			
		×	*O. spiriferoides*, M'Coy															
			O. Bailyana, Dav.															
			O. fallax, Salt.										?	×				
			O. girvanensis, Dav.															
			O. intercostatus, Portl.															

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Brachiopoda —*cont.*			*O. interplicata*, M'Coy															
			O. parva, Pand.		—	—			—	—								
			O. patera, Salt.							—								
			O. plicata, Sow.		—	—					—	—						
			O. protensa, Sow.			—	—			—	—		?	×	×			
			O. pseudopecten, M'Coy															
			O. proava, Salt.				—											
			O. Salteri, Dav.							—								
			O. sarmentosa, M'Coy				—											
			O. semicircularis, Sow.					—										
			O. Sowerbyana, Dav.					—						×	×		×	
			O. tricenaria, Conrad.											×				
			O. unguis, Sow.				—			—		—						
			O. porcata, M'Coy	—	—	—	—	—	—	—	—			×	×			
			O. sagittifera, M'Coy				—				—			×				
		×	*O. simplex*, M'Coy				—	—										
		×	*O. testudinaria*, Dalm.	—	—	—	—	—	—	—	—	—		×	×			
		×	*O. turgida*, M'Coy	—	—	—	—	—						×				
		×	*O. vespertilio*, Sow.	—	—	—	—	—	—	—	—			×				
			O. triangularis, Sow.							—								
			Orthisina adscendens, Pand.		—		—											
			Rhynchonella borealis, Schloth.									—		×	×	×		
			R. æmula, Salt.		—					—		—						
			R. nasuta, M'Coy									—		×				
			R. Portlockiana, Dav.															
			R. Salteri, Dav.	—		—						—						
			R. (Meristella) subundata, M'Coy.											×				
			R. Thomsoni, Dav.									—						
			R. upsilon, Barr.	—								—						
		×	*Siphonotreta micula*, M'Coy	—			—					—						
			S. alternata, Con.			—						—		×	×			
			Strophomena antiquata		—	—					—	—		×	×	×	×	×
			S. grayiæ, Dav.									—						
			S. Holli, Dav.							—	—							
			S. deltoidea, Conrad		—	—	—			—	—	—						
		×	*S. expansa*, Sow.	—	—	—	—	—		—	—	—		×				
			S. grandis, Sow.	—	—	—	—	—		—	—	—						
			S. pecten, Linn.	—	—			—			—	—		×	×	×	×	×
			S. complanata, Sow.							—								
			S. cancellata, Portl.															
			S. compressa, Sow.	—	—	—	—			—	—	—			×	×	×	
			S. concentrica, Portl.									—						
		×	*S. corrugatella*, Dav.							—	—	—						
			S. deltoidea, Conrad		—	—	—			—	—	—						
			S. Jukesii, Dav.									—						
			S. retroflexa, Salt.									—						
		×	*S. rhomboidalis*	—	—	—	—	—	—	—	—	—		×	×	×	×	×
			S. funiculata, M'Coy									—						
			S. plicatis, M'Coy									—						
			S. siluriana, Dav.								—							
		×	*S. simulans*, M'Coy	—	—	—	—								×			
			S. ungula, M'Coy		—													
			Triplesia Grayiæ, Dav.						—			—						
			T. Maccoyana, Dav.				—											
			T. monilifera, M'Coy								—							
			T. productoides, M'Coy															
			Porambonites intercedens, Pander.									—						
			Acrotreta Nicholsoni, Dav.									—						
Lamellibranchiata.			*Ambonychia carinata*, Conrad.					loc. doubtful.										
			A. contorta, Portl.															
			A. gryphus, Portl.															
			A. prisca, Portl.															
			A. transversa, Portl.															
			A. trigona, Münst.															
			A. triton, Salt.							—								
			A. undata														?	?
			Arca Edmondiiformis, M'Coy.				—	—					—				×	×
			Ctenodonta obliqua, Portl.					—										
			C. lævis, Sow.		—													

Classes.	Pass up from: Arenig.	Pass up from: Llandeilo.	Caradoc or Bala Species.	North Wales: Caernarvonshire.	North Wales: Denbighshire.	North Wales: Montgomeryshire.	North Wales: Merionethshire.	South Wales: Pembrokeshire.	South Wales: Carmarthenshire.	England: Shropshire.	England: Westmoreland.	Scotland.	Ireland.	Pass to: Lower Llandovery.	Pass to: Upper Llandovery.	Pass to: Woolhope.	Pass to: Wenlock.	Pass to: Ludlow.
Lamellibranchiata—*cont.*			*C. varicosa*, Salt.															
			C., sp.															
			C. lævata, Hall															
			C. ambigua, Portl.															
			C. anglica, D'Orb.														×	×
			C. dissimilis, Portl.															
			C. imbricata, Portl.															
			C. obliqua, Portl.															
			C. protei, Münst.															
			C. quadrata, M'Coy															
			C. regularis, Portl.															
			C. scitula, M'Coy															
			C. semitruncata, Portl.															
			C. subacuta, M'Coy															
			C. transversa, Portl.															
			Cucullella antigua ??, Sow.												×		×	×
			Modiolopsis obliqua, Sow.															
			M. nilssoni, His.															
			M. pyrus, Salt.															
			M., sp.															
			M., sp.															
			M., sp.															
			M. Modiolaris, Conrad.															
			M. antiqua, Sow.												×		×	
			M. Bryceii, Portl.															
			M. nerei, Münst.															
	×		*M. expansus*, Portl.															
			M. gradata, Salt.														×	×
	×		*M. inflata*, M'Coy															
			M. modiolaris, Conrad.															
			M. orbicularis, Sow.															
			M. (orthonota) postlineatus, M'Coy.															
			Pterinea pleuroptera, Conrad.															×
			P. lineata, Goldf.															
			P., sp.															
			P., sp.															
			Avicula venusta, Münst.															
			A. (Pterinea) elongata, Goldf.															
			A. (Pterinea) fimbriata, M'Coy.															
			A. (Pterinea) orbicularis, M'Coy.															
			A. (Pterinea) retroflexa, Wahl.												×	×	×	×
			A. (Pterinea) sublævis, M'Coy.															
			A. (Pterinea) tenuistriata, M'Coy.													×	×	×
			Orthonota versimilis, Salt.															×
			O. nasuta, Conrad.															
			O. semisulcata, Sow.												×			
			O. simplex, Portl.															×
			O. sulcata, His.												×		×	×
			Palæarca bulla, Salt.															
			P. obscura, Salt.															
			P. modiolaris, Salt.															
			P. quadratus, Salt.															
			P. Billingsiana, Salt.															
			Cardiola semirugata, Portl.															
	×		*C. interrupta*, Sow.													×	×	×
			C. striata, Sow.													×	×	×
			Mytilus carinatus, Portl.												×	×	×	
			M. mytilimeris, Conrad															×
			M. similimus, Forbes															
			M. cinetus, Portl.															
			Pleurorhynchus dipterus, Salt.															
			Anodontopsis securiformis, M'Coy.															
	×		*Megalomus*															
			Clidophorus ovalis, M'Coy															
			Lyrodesma plana, Conrad		?													

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Gasteropoda		×	*Cyclonema crebristria*, M'Coy.	—	—	—	—		—	—		—		×	×			
			C. concinna, M'Coy															
			C. rupestris, Eichw.															
			C. sulcifera, Eichw.															
			Euomphalus alatus, His.												×		×	×
			E. lineatus, Portl.															
			E. granulatus, Münst.															
			E. parvus, Portl.															
			E. sculptus, Sow.												×		×	
			E. subsulcatus, His.															
			E. tubæformis, Baily															
			Holopea concinna, M'Coy		—													
			H. striatella, Sow.	—														
			H. lymnæoides, Forbes															
			H. exserta, Forbes															
			H. carinata, Forbes															
			H. conica, Forbes															
			H. constricta, M'Coy															
			Holopella cancellata, Sow.											×	×			×
			H. conica? Sow.	—											×			×
			H. monile, M'Coy		—													
			H. tenuicincta, M'Coy											×	×			
			Macrocheilus elongatus, Portl.															
			Murchisonia angulata, Sow.	—										×				
			M. bicincta, M'Coy					?										
			M. gyrogonia, M'Coy	—		—	—							×				
			M. obscura, Portl.															
			M. scalaris, Salt.	—														
			M. subrotunda, Portl.															
		×	*M. simplex*, M'Coy	—	—	—	—											
			M. cancellatala, M'Coy			—								×	×			
			M. pulchra, M'Coy	—		—	—							×	×			
			M. turrita, Portl.		—		—											
			Ophileta macromphala, M'Coy.															
			Platyschisma helicites, Sow.												×			?
			Patella saturni, Goldf.						—	—								
			Pleurotomaria latifasciata, M'Coy.							—								
			P. Moorei, Salt.											×				
			P. trochiformis, Portl.				—											
			Trochonema lyrata, M'Coy.		—													
			T. tricincta, M'Coy				—								×			
			T. triporcata, M'Coy		—		—											
			T. trochleata, M'Coy											×	×			
			Trochus Moorei, M'Coy												×			
			T. multitorquatus, M'Coy												×			
			Turbo rupestus, Eichw.															
		×	*T. tritorquatus*, M'Coy											×	×	×		
			Raphistoma lenticularis, Sow.	—		—				—				×	×			
			R. æqualis, Salt.	—		—	—											
			R. elliptica, His.	—		—	—						?		×			
			R., sp.	—	—	—	—											
			R., sp.	—	—	—	—											
			R. parva, Hall															
Pteropoda			*Theca triangularis*, Portl.			—	—		—	—		—						
			T. anceps, Salt.							—								
			T. reversa, Salt.				—		—									
			Pterotheca transversa, Portl.															
			P. undulata, Salt.															
			P. corrugata, Salt.	—														
			Conularia cancellata, Sandb.										?					
			C. elongata, Portl.								—							
			C. lævigata, Salt.				—											
			C. Sowerbii, Defr.				—			—		—		×			×	×

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Heteropoda -			*Ecculiomphalus Bucklandii*. Portl.															
		×	*E. scoticus*, M'Coy - -												×			
		×	*Bellerophon bilobatus*, Sow.												×	×		
			B. alatus, Portl. - -															
		×	*B. perturbatus*, Sow. -															
			B. carinatus, Sow. -											×	×			×
			B. dilatatus, Sow. - -															
			B. nodosus, Salt. - -													×		
			B. expansus, Sow. -												×			×
			B. sub-decussatus, M'Coy												×			
			B. sulcatinus, Emm. -															
			B. acutus, Sow. - -												×	×	×	
		×	*Maclurea macromphala*, M'Coy.															
			M. M'Coyi, Salt. - -															
		?	*M. magna*, Lesseur - -															
Cephalopoda			*Cyrtoceras inæquiseptum*, Portl.															
			C. sonax, Salt. - -															
			C. atramentarium, Salt. -															
			Endoceras protæiforme, Hall.											?				
			Koleoceras pseudoregulare, Portl.															
			K. pseudospeciosum, Portl.															
			Lituites anguiformis, Salt.															
			L. cornu-arietes, Sow. -											×	×	×	×	
			L. undosus ? Sow. - -															
			L., var. - - -															
			L. planorbiformis, Conrad															
			L. hibernicus, Salt. -						?									
			Phragmoceras nautileum, Sow.														×	×
			Poterioceras approximatum, M'Coy.															
			Trocholites hibernicus, Salt.															
			Orthoceras ibex, Sow. -											×	×		×	
			O. vagans, Salt. - -											×				
			O. audax, Salt. - -															
			O. annulatum, Sow. -											×				
		×	*O. arcuoliratum*, Hall -															
			O. bilineatum, Hall. -												×			
			O. breviconicum, Portl. -															
			O. Brongniarti, Troost. -															
			O. elongato-cinctum, Portl.															
			O. angulatum, Wahl. -												×	×	×	
			O. filosum, Sow. - -												×		×	
			O. gracile, Portl. - -															
			O. gregarium, Sow. -												+		×	
			O. incertum, Portl. -															
			O. irregulare, Münst. -															
			O. lineatum. His. - -															
			O. laqueatum, Hall -															
			O. perannulatum, Portl. -															
			O. Barrandii, Salt -											×				
			O. politum, M'Coy -											×	×			
			O. pomeroense, Portl. -															
			O. regulare, Münst. -															
			O. subannulatum, Münst.															
			O. subarcuatum, Portl. -															
			O. primævum ? Forbes -													×	×	
			O. subundulatum, Portl. -													×	×	×
			O. tenuicinctum, Portl. -												×		×	×
			O. tenuistriatum, Münst.											×	×			
			O. tumidum, Portl. -															
			O. vaginatum, Schloth. -															
			O. ? ventricosum, Sharpe -															
			O. vagans, Salt. - -											?				

R. E.

Caradoc.

[In addition to the accompanying tabulated form it is advisable to distribute the extensive group of fossils occurring in the Caradoc or Bala series geographically and in localities through the four counties in North Wales. The species in the several localities are all taken from the Survey Catalogue and from collections made in the field during the progress of the Survey in North Wales.

The chief localities only are given; those yielding only two or three species are omitted, such having no distributional value, unless under peculiar circumstances. Additional interest is attached to the fossils being thus distributed, as those desirous to collect will know the typical localities. The large fauna of the Caradoc Rocks, numbering 613 species, added to the number of localities where occurring, is an additional reason for thus preparing and placing them in localities. For the four North Wales counties the number of species occurring in each, are—

Caernarvonshire - - -	115	distributed in	10 chief localities.
Denbighshire - - -	134	„	6 „
Montgomeryshire - - -	133	„	5 „
Merionethshire - - -	161	„	10 „

It may be interesting also to state the distribution as regards number of species through South Wales, England, Scotland, and Ireland.

South Wales	Pembrokeshire - -	93 species.
	Carmarthenshire - -	114 „
England	Shropshire - - - -	117 „
	Westmoreland - - -	100 „
Scotland - - - - -	198	„
Ireland - - - - - -	300	„

The number of species known in North Wales is 276, and in South Wales 135, and their occurrence in the four N.W. counties is as above, 543. The remaining species completing the fauna of the Caradoc group, are distributed through South Wales, England, Scotland, and Ireland, whose fossils, as a whole, we are not here called upon to discuss.] R. E.

List of North Welsh Caradoc Fossils arranged in the Chief Localities in the North Welsh Counties.

MONTGOMERYSHIRE.

Llanfyllin -	*Fucoids.* *Sponge spiculæ.* Actinozoa. *Favosites asnera*, D'Orb. *F. fibrosus*, Goldf. *Monticulipora petropolitana*, Pand. *Heliolites interstincta*, Wahl. *H. tubulatus*, Lonsd. *Aulocophyllum mitratum*, His. *Cyathophyllum.* Cystidea. *Echinosphærites balticus*, Eichw. *Hemicosmites squamosus*, Forbes. Annelida. *Tentaculites anglicus*, Salt. Asteread. *Palæaster imbricatus*, Salt. Crustacea. *Asaphus radiatus*, Salt. *Calymene brevicapitata*, Portl. *Cheirurus juvenis*, Salt. *Cybele verrucosa*, Dalm. *C.* sp.	Llanfyllin—*cont.*	*Homalonotus bisulcatus*, Salt. *Illænus Bowmanii*, Salt. *Lichas laxatus*, M'Coy. *Phacops apiculatus*, Salt. *P. Brongniartii*, Portl. *Trinucleus concentricus*, Eaton. *Leperditia umbonata*, Salt. Polyzoa. *Fenestella.* *Ptilodictya dichotoma,* *P. acuta*, Hall. *P. explanata*, M'Coy. *Phyllopora*, 2 sp. *Glauconome disticha*, Goldf. Brachiopoda. *Atrypa marginalis*, Dalm. *Discina oblongata*, Portl. *D.*, sp. *Leptæna scissa*, Salt. *L. sericea*, Sow. *L. tenuicincta*, M'Coy. *L. transversalis*, Wahl. *L. quinquecostata*, M'Coy. *Lingula ovata*, M'Coy. *Orthis actoniæ*, Sow. *O. flabellulum*, Sow. *O. alternata*, Sow. *O biforata*, Schloth. *O. calligramma*, Dalm. *O. crispa*, M'Coy.

LLANFYLLIN—*cont.*	*O. elegantula*, Dalm. *O. insularis*, Eichw. *O. porcata*, M'Coy. *O. testudinaria*, Dalm. *O. vespertilio*, Sow. *O.* sp. *spiriferoides*, M'Coy. *Strophomena alternata*, Con. *S. antiquata*, Sow. *S. rhomboidalis.* *S. expansa*, Sow. *S. grandis*, Sow. LAMELLIBRANCHIATA. *Ctenodonta varicosa*, Salt. *Arca Edmondiiformis*, M'Coy. *Pterinea.* *Orthonota.* GASTEROPODA. *Cyclonema crebristria*, M'Coy. *C.*, sp. *Raphistoma æqualis*, Salt.
LLANWDDYN -	PROTOZOA. *Stromatopora striatella*, D'Orb. ACTINOZOA. *Favosites fibrosus*, Goldf. ANNELIDA. *Tentaculus anglicus*, Salt. CRUSTACEA. *Asaphus Powisii*, Murch. *Calymene Blumenbachii*, Brong. *C. brevicapitata*, Portl. *Cheirurus.* *Cybele verrucosa*, Dalm. *Homalonotus bisulcatus*, Salt. *Lichas laxatus*, M'Coy. *Phacops apiculatus*, Salt. *P. conicopthalmus*, Bœck. *P. Brongniarti*, Portl. *Trinucleus concentricus*, Eaton. *T. seticornis*, His. *Beyrichia complicata*, Salt. *Leperditia* (*Cythere*) *umbonata*, Salt. POLYZOA. *Fenestella*, 2 sp. BRACHIOPODA. *Leptæna sericea*, Sow. *Lingula tenuigranulata.* *Orthis actoniæ*, Sow. *O. alternata*, Sow. *O. flabellulum*, Sow. *O. biforata*, Schloth. *O. calligramma*, Dalm. *O. elegantula*, Dalm. *O. spiriferoides*, M'Coy. *O. porcata*, M'Coy. *O. vespertilio*, Sow. *Atrypa marginalis*, Dalm. *Strophomena rhomboidalis.* *S. expansa*, Sow. LAMELLIBRANCHIATA. *Ctenodonta varicosa.* GASTEROPODA. *Murchisonia simplex*, M'Coy. HETEROPODA. *Bellerophon nodosus*, Salt.
MEIFOD - -	ACTINOZOA. *Favosites aspera*, D'Orb. *F. fibrosus.* *F. Lycopodites.* *Heliolites megastoma*, M'Coy. *Petraia uniseriales*, M'Coy. *P. rugosa*, Phill. *Halysites catenularius*, Linn. CRUSTACEA. *Asaphus Powisii*, Murch. *Calymene brevicapitata*, Portl. *Cybele rugosa*, Portl. *Homalonotus bisulcatus*, Salt. *Phacops alifrons* Salt. *P. apiculatus*, Salt. *P. conicopthalmus*, Bœck. *Trinucleus concentricus.* *Leperditia* (*Cythere*) *umbonata.* POLYZOA. *Fenestella*, 2 sp. *Ptilodictya dichotoma.* BRACHIOPODA. *Atrypa marginalis*, Dalm. *Leptæna sericea*, Sow. *L. tenuicincta*, M'Coy. *L. transversalis*, var. *undulata*, Wahl. *Lingula.* *Orthis alternata*, Sow. *O. flabellulum*, Sow. *O. biforata*, Schloth. *O. flexicostata*, M'Coy. *O. calligramma*, Dalm. *O. crispa*, M Coy. *O. elegantula*, Dalm. *O. spiriferoides*, M'Coy. *O. porcata*, M'Coy. *O. testudinaria*, Dalm. *O. vespertilio*, Sow. *O. actoniæ*, Sow. *Strophomena deltoidea.* *S. expansa*, Sow. *S. rhomboidalis.* LAMELLIBRANCHIATA. *Palæarca bulla*, Salt. *P. obscura*, Salt. GASTEROPODA. *Cyclonema crebristria*, M'Coy. *Murchisonia simplex*, M'Coy. *M. pulchra*, M'Coy. *M. cancellatula*, M'Coy, *Raphistoma lenticularis*, Sow. *Bellerophon bilobatus*, Sow.
LLANGEDWYN -	*Favosites aspera*, D'Orb. CRUSTACEA. *Asaphus Powisii*, Murch. *Calymene brevicapitata.* Portl. *Homalonotus bisulcatus*, Salt. *Trinucleus concentricus*, Eaton. BRACHIOPODA. *Orthis alternata*, Sow. *O. elegantula.* Dalm. *O. vespertilio*, Sow. *O. flabellulum.* Sow. *Leptæna sericea*, Sow. GASTEROPODA. *Murchisonia gyrogonia*, M'Coy. *M. simplex*, M'Coy.

	HETEROPODA.	LLECHWEDDWYD	*Ptilodictya acuta*, Hall.
LLANGEDWYN—*cont.*	*Bellerophon bilobatus*, Sow. *B. carinatus*, Sow. *B. nodosus*, Salt.	ALLT-YR-ANKER	*Leptæna transversalis*, var. *undulata*, Wahl. *Murchisonia cancellatula*, M'Coy.
WELSHPOOL -	*Favosites fibrosus*, Goldf. *Monticulipora favulosa*, Phill. *Palæaster asperimus*, Salt.	LLANFAIR - -	*Orthis turgida*, M'Coy.
	CRUSTACEA.	GAER FAWR -	*Orthis testudinaria*, Dalm. *Strophomena simulans*, M'Coy.
	Asaphus Powisii, Murch. *Orthis elegantula*, Sow. *O. spiriferoides* M'Coy. *O. porcata*, M'Coy. *O. testudinaria*, Dalm. *O. vespertilio*, Sow. *O. calligramma*, Dalm.	CADER DINMAEL	*Strophomena expansa*, Sow.
ALT-GOCH - -	*Heliolites tubulatus*, Lonsd.	LLANFECHAN -	*Murchisonia gyrogonia*, M'Coy.
NR. LLANGYNOG.	*Amnyx nudus*, Murch. *Beyrichia complicata*, Salt. *Orthis alternata*, Sow.	E. OF BERWYN -	*Bellerophon carinatus*, Sow.

R.E.

MERIONETHSHIRE.

	CŒLENTERATA.		GASTEROPODA.
E. OF BALA LAKE.	*Favosites aspera*, D'Orb. *F. fibrosus*, Goldf. *Monticulipora* (*Nebulipora*) *favulosa*, Phill. *M.* (*Chetetes*) *petropolitana*, Pand.	E. OF BALA LAKE—*cont.*	*Cyclonema crebristria*, M'Coy.
	ANNELIDA.		HETEROPODA.
	Tentaculites anglicus, Salt. *Serpulites.*		*Bellerophon bilobatus.* *B. nodosus*, Salt.
	ECHMODERMITA.		CŒLENTERATA.
	Cystidea. *Glyptocrinus basalis*, M'Coy.	W. OF BALA LAKE.	*Favosites fibrosus*, Goldf. *F.*, var. *ramulosa?* *Monticulipora* (*Nebulipora*) *favulosa*, Phill. *M.* (*Chetetes*) *petropolitanus*, Pand.
	CRUSTACEA.		ANNELIDA.
	Asaphus Powisii, Murch. *Calymene Blumenbachii*, Brong. *Cheirurus bimucronatus*, Murch. *Homalonotus bisulcatus*, Salt. *Illænus Davisii*, Salt. *Lichas laxatus*, M'Coy. *Phacops apiculatus*, Salt. *Trinucleus concentricus*, Eaton. *Harpes.* *Beyrichia complicata*, Salt. *Leperditia* (*Cythere*) *umbonata*, Salt.		*Tentaculites anglicus*, Salt. *Serpulites.* *Scoleroderma*, flattened sp. *S. cylindrical*, sp.
	BRYOZOA.		ECHINODERMATA CYSTIDEA.
	Ptilodictya fucoides, M'Coy.		*Sphæronites Litchii*, Forbes. *S. munitus*, Forbes. *S. pyriformis*, Forbes. *S. punctatus*, Forbes. *Echinosphærites Balticus*, Eichw.
	BRACHIOPODA.		ASTEROIDA.
	Leptæna sericea, Sow. *L. scissa*, Salt. *Lingula ovata*, M'Coy. *Orthis actoniæ*, Sow. *O. alternata*, Sow. *O. flabellulum*, Sow. *O. sagittifera*, M'Coy. *O. calligramma*, Dalm. *O. spiriferoides*, M'Coy. *O. testudinaria*, Dalm. *O. vespertilio*, Sow. *Strophomena rhomboidalis.* *S. expansa*, Sow.		*Palæaster obtusus*, Forbes.
	LAMELLIBRANCHIATA.		CRUSTACEA.
	Ctenodonta varicosa, Salt. *Modiolopsis obliqua*, Sow. *M.* like *Nilssoni*, His. *M. post-lineatus.*		*Agnostus trinodus*, Salt. *A.*, sp. *Asaphus Powisii*, Murch. *Calymene brevicapitata.* *Cheirurus bimucronatus*, Murch. *Cybele rugosa*, Portl. *Encrinurus sexcostatus*, Salt. *Homalonotus bisulcatus*, Salt. *Illænus Davisii*, Salt. *Lichas laxatus*, M'Coy. *Phacops apiculatus*, Salt. *P. Bronguiarti*, Portl. *P. mucronatus*, Brong. *Remopleurides Colbii*, Portl. *R.*, allied to *radians*, Barr. *R. longicostatus*, Portl. *Trinucleus concentricus*, Eaton. *T. seticornis*, His. *Beyrichia complicata*, Salt.

W. of Bala Lake—*cont.*	*Primitia* (*Beyrichia*) *strangulata*, Salt. *Leperditia* (*Cythere*) *umbonata*, Salt. **Bryozoa.** *Ptilodictya dichotoma*, Portl. *Berenicea heterogyra*, M'Coy. **Brachiopoda.** *Leptæna sericea*, Sow. *L. quinquecostata*, M'Coy. *L. tenuicincta*, M'Coy. *L. scissa*, Salt. *Orthis actoniæ*, Sow. *O. flabellulum*, Sow. *O. biforata*, Schloth. *O. spiriferoides*, M'Coy. *O. simplex*, M'Coy. *O. vespertilio*, Sow. *Rhynchonella*, Wahl. *Strophomena rhomboidalis.* *S. expansa*, Sow. **Lamellibranchiata.** *Ctenodonta obliqua*, Portl. *C. varicosa*, Salt. *Modiolopsis*, like *Nilssoni.* **Gasteropoda.** *Holopea striatella*, Sow. *H. exserta*, Forbes. *H. carinata*, Forbes. *H. conica*, M'Coy. *Murchisonia simplex*, M'Coy. *Euomphalus.* *Raphistoma æqualis*, Salt. *R.*, 2 sp. **Pteropoda.** *Theca reversa*, Salt. **Heteropoda.** *Bellerophon bilobatus*, Sow. *B. nodosus*, Salt. **Cephalopoda.** *Cyrtoceras atramentarium*, Salt. *Lituites cornu-aristis*, Sow.
N. of Bala Lake.	*Monticulipora* (*Nebulipora*) *favulosa*, Phill. *Scolicoderma.* **Crustacea.** *Calymene.* *Cheirurus juvenis*, Salt. *Encrinurus sexcostatus*, Salt. *Homalonotus bisulcatus*, Salt. *Illænus Davisii*, Salt. *Trinucleus concentricus*, Eaton. *Leperditea* (*Cythere*) *umbonata.* **Hydrozoa.** *Diplograptus pristis?* His. **Brachiopoda.** *Leptæna sericea*, Sow. *L. tenuicincta*, M'Coy. *Lingula ovata*, M'Coy. *Siphonotreta micula*, M'Coy. *Strophomena.* **Lamellibranchiata.** *Ctenodonta varicosa*, Salt.
N. of Bala Lake—*cont.*	**Gasteropoda.** *Cyclonema crebristria*, M'Coy. *Holopea concinna*, M'Coy. **Heteropoda.** *Bellerophon nodosus*, Salt.
Corwen - -	*Favosites fibrosus*, Goldf. *Trinucleus concentricus*, Eaton. *Diplograptus foliaceus*, His. *Fenestella Milleri*, Lonsd. *Ptylodictya fucoides*, M'Coy. **Brachiopoda.** *Crania divaricata*, M'Coy. *Orthis elegantula*, Dalm. *O. porcata*, M'Coy. *O. vespertilio*, Sow. *Orthisina adscendens*, Pand.
S.E. of Bala Lake.	**Cœlenterata.** *Favosites fibrosus*, Goldf. *Monticularia* (*Nebulipora*) *favulosa*, *Phill.* *Petraia.* **Crustacea.** *Calymene brevicapitata*, Portl. *Homalonotus bisulcatus*, Salt. *Leperditia* (*Cythere*) *umbonata*, Salt. **Bryozoa.** *Fenestella*, n. sp. **Brachiopoda.** *Leptæna sericea*, Sow. *Orthis alternata*, Sow. *O. flabellulum*, Sow. *O. spiriferiodes*, M'Coy. *O. vespertilio*, Sow. *Strophomena rhomboidalis.* *S. expansa*, Sow. **Gasteropoda.** *Cyclonema crebristria*, M'Coy. **Cephalopoda.** *Orthoceras ibex*, Sow. *O. vagans*, Salt. *O. audax*, Salt. *O.*, sp. *O.*, smooth sp. with fine longitudinal *striæ.*
Bala - - -	**Cœlenterata.** *Favosites* (*Stenopora*) *Lycoperdon.* *Heliolites megastoma*, M'Coy. **Brachiopoda.** *Atrypa marginalis*, Dalm. *Leptæna transversalis*, Wahl. *Orthis biforata*, var. *fissicostata*, M'Coy. *Strophomena rhomboidalis.* *Strophomena deltoidea*, Con. *S. grandis*, Sow. **Lamellibranchiata.** *Arca Edmondiiformis*, M'Coy. *Palæarca modiolaris*, Salt. **Gasteropoda.** *Murchisonia turrita*, Portl.

N. of Corwen -	*Monticulipora (Nebulipora) favulosa* *Cheirurus juvenis*, Salt. *C. octolobatus*, M'Coy. *Illænus Davisii*, Salt. *Phacops alifrons*, Salt. *Orthis actoniæ*, Sow.	Pentre-cwm-ddu, S. of Glyndiffro.	*Diplograptus foliaceus*, His.
		N. of Tremadoc.	*Mono. sagittarius*, Linn. *Murchisonia pulchra*, M'Coy.
	Cystidea.	Cerrig-cordog	*Fenestella Milleri*, Lonsd.
Rhiwlas - -	*Echinosphærites granatum*, Walh. *Hemicosmites pyriformis*, V. Buch. *Pleurocystites.*	Pont-y-Glyn (Diffwys).	*Crania divaricata*, M'Coy. *Orthis alternata*, Sow. *Siphonotreta micula*, M'Coy.
	Crustacea.		Brachiopoda.
	Ampyx tumidus, Forbes. *Cheirurus juvenis*, Salt. *Staurocephalus Murchisoni*, Barr. *Trinucleus seticornis*, His. *Illænus Davisii*, Salt. *Cheirurus bimucronatus*, Murch. *Asaphus radiatus.*	Llanrhaiadr	*Orthis flabellulum*, Sow. *O. elegantula*, Dalm. *O. insularis*, Eichw. *O. spiriferoides*, M'Coy. *Strophomena expansa*, Sow.
	Brachiopoda.		Brachiopoda.
	Leptæna tenuicincta, M'Coy.	Aber Hirnant	*Orthis vespertilio*, M'Coy. *O. Hirnantensis*, Schloth. *O. biforata*, var. *flexicostata*, M'Coy. *O. sagittifera*, M'Coy. *Arca Edmondiformis*, M'Coy.
	Gasteropoda.		
	Holopæa Lymnæoides, Forbes.	Maes-y-fallen	*Orthis Hirnantensis*, M'Coy.
	Cephalopoda.	Cwm-erthen -	*Orthis Hirnantensis*, M'Coy.
	Cyrtoceras sonax, Salt. *C.*, sp. *Lituites.*	S. of Llangollen.	*Orthis elegantula*, Dalm.
N.E. of Bala Lake.	*Trinucleus seticornis*, His. *Lingula ovata*, M'Coy.	Betws-y-coed -	*Palæarca quadrata*, Salt.
Dinas Mowddwy.	*Orthis spiriferoides*, M'Coy. *Bellerophon bilobatus*, Sow.	S. of Cerrig-y-Druidion.	*Orthis elegantula*, Dalm.
		S.E. of Cerrig-y-Druidion.	*Orthis elegantula*, Dalm.

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Bettws-y-coed	*Monticulipora (Nebulipora) favulosa*, Phill. *Glyptocrinus basalis.*	Bettws-y-coed —*cont.*	Gasteropoda.
	Crustacea.		*Murchisonia simplex*, M'Coy. *M.*, sp. *Raphistoma æqualis*, Salt.
	Asaphus Powisii. *Homalonotus bisulcatus*, M'Coy. *Phacops conicophthalmus*, Bœck. *Trinucleus concentricus*, Eaton.	Pwllheli - -	*Tentaculites anglicus*, Salt.
	Brachiopoda.		Crustacea.
	Leptæna sericea, Sow. *L. scissa*, Sow. *Orthis actoniæ*, Sow. *O. flabellulum*, Sow. *O. biforata*, Schloth. *O. calligramma*, Dalm. *O. crispa*, M'Coy. *O. elegantula*, Dalm. *O. porcata*, M'Coy. *O. testudinaria*, Dalm. *O. turgida*, M'Coy. *Strophomena rhomboidalis.* *S. expansa*, Sow.		*Calymene Blumenbachii*, var. *Caractaci*, Salt. *Homalonotus bisulcatus*, Salt. *Phacops apiculatus*, Salt. *Trinculeus concentricus*, Eaton.
			Brachiopoda.
			Orthis spiriferoides, M'Coy. *Strophomena expansa*, Sow.
	Lamellibranchiata.	Ysfytty Evan -	*Echinosphærites Davisii*, M'Coy. *Edmondia.* *Atrypa marginalis*, Dalm. *Orthis calligramma*, Dalm. *Murchisonia gyrogonia*, M'Coy. *Bellerophon bilobatus*, Sow.
	Clenodonta lævis, Sow. *C. varicosa*, Salt. *Modiolopsis obliqua*, Sow. *M.*, sp. *M.*, 4 sp.	Llyn Ogwen -	*Orthis flabellulum*, Sow.

BODUAN - -	*Orthis flabellulum*, Sow. *O. testudinaria*, Dalm. *Strophomena grandis*, Sow.
GLYN CEIRIOG -	*Strophomena simulans*, M'Coy. *S. pecten*, Linn.
LLANGOLLEN -	*Strophomena simulans*, M'Coy. *S. pecten*, Linn.
MOEL SIABOD -	*Favosites fibrosa*, Goldf. *Asaphus Powisii*, Murch. *Orthis elegantula*, Sow. *Murchisonia simplex*, M'Coy. *Orthoceras audax*, Salt.
SNOWDON - -	*Strophomena rhomboidalis*, Wilck.
CARNEDD DAFYDD. -	*Favosites fibrosa*, Goldf. *Tentaculites anglicus*, Salt.
	CRUSTACEA. *Cybele verrucosa*, Dalm. *Homalonotus bisulcatus*, Salt. *Trinucleus concentricus*, Eaton. *Leperditia* (*Berychia*) *complicata*, Salt.
	BRYOZOA. *Fenestella*, 2 sp.
	BRACHIOPODA. *Discina*. *Leptæna sericea*, Sow. *Orthis flabellulum*, Sow. *O. elegantula*, Dalm. *Rhynchonella*, like *serrata*. *R.*, sp. *Strophomena rhomboidalis*, Wilck. *S. expansa*, Sow.
	LAMELLIBRANCHIATA. *Ctenodonta*, sp. *Modiolopsis*, 4 sp.
	GASTEROPODA. *Cyclonema crebristria*, M'Coy. *Murchisonia angulata*, Sow. *M. scalaris*, Salt. *Raphistoma lenticularis*, Sow.
	HETEROPODA. *Bellerophon perturbatus*, Sow.
	CEPHALOPODA. *Cyrtoceras*, sp.
DOLWYDDELAN -	CŒLENTERATA. *Favosites fibrosa*, Goldf. *Monticularia* (*Nebulipora*) *favulosa*, Phill.
	CRUSTACEA. *Asaphus Powisii*, Murch. *Calymene Blumenbachii*, var. CARACTACI, Salt.
DOLWYDDELAN —*cont.*	*Homalonotus bisulcatus*, Salt. *Trinucleus concentricus*, Eaton. *Leperditia* (*Cythere*) *umbonata*, Salt.
	BRACHIOPODA. *Leptæna sericea*, Sow. *Orthis flabellulum*, Sow. *O. calligramma*, Dalm. *O. elegantula*, Dalm. *O. spiriferoides*, M'Coy. *O. turgida*, M'Coy. *O. vespertilio*, Sow. *Strophomena expansa*, Sow. *S. grandis*, Sow.
	LAMELLIBRANCHIATA. *Ctenodonta lævis*, Sow. *C.*, sp. *Orthonota*, sp.
PENMACHNO -	*Favosites fibrosa*, Goldf.
	CRUSTACEA. *Phacops aliffrons*, Salt. *Leperditia* (*Berychia*) *complicata*.
	BRACHIOPODA. *Orthis actoniæ*, Sow. *O. alternata*, Sow. *O. spiriferoides*, M'Coy. *O. testudinaria*, Dalm. *O. vespertilio*, Sow.
LLYN-IDWAL -	*Favosites fibrosa*, Goldf.
	BRACHIOPODA. *Leptæna sericea*, Sow. *Orthis flabellulum*, Sow. *O. elegantula*, Dalm. *Strophomena rhomboidalis*, Wilck.
	GASTEROPODA. *Murchisonia scalaris*, Salt. *Raphistoma lenticularis*, Sow.
	HETEROPODA. *Bellerophon carinatus*, Sow. *B. nodosus*, Salt.
E. OF Y-TRYFAN, LLYN-OGWEN.	*Favosites, fibrosa*, Goldf. *Cornulites serpularius*, Schloth. *Rhynchonella*, like *serrata*.
CONWAY - -	*Favosites* (*Stenopora*) *Lycoperdon*. *Trinucleus concentricus*, Eaton. *Climacograptus bicornis*. *Diplograptus foliaceus*, Murch. *Dicranograptus clingani*, Carr. *Idiograptus margaritaceus*, Lapw.
CONWAY FALLS -	*Leperditia* (*Cythere*) *umbonata*. *Diplograptus pristis*, His. *Orthis turgida*, M'Coy.

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GLYN GEIRIOG -	CŒLENTERATA. *Favosites aspera*, D'Orb. *F. Lycoperdon*. *Heliolites interstinctus*, Wahl.
GLYN GEIRIOG —*cont.*	*H. megastoma*, M'Coy. *Petraia*. *P. unirserialis*, M'Coy. *P. subduplicata*, M'Coy.

GLYN GEIRIOG —*cont.*	ANNELIDA. *Tentaculites anglicus*, Salt. CRUSTACEA. *Acidaspis Brightii*, Murch. *Phacops apiculatus*, Salt. *P. conicopthalmus*, Boeck. *P. macroura*, Sjog. HYDROZOA. *Diplograptus pristis*, His. BRYOZOA. *Fenestella Millerí*, Lonsd. *Phyllopora Hisingeri.* *Ptilodictya costellata*, M'Coy. *P. explanata*, M'Coy. *P. acuta*, Hall. *Glauconome disticha*, Goldf. BRACHIOPODA. *Atrypa marginalis*, Dalm. *Leptæna transversalis*, Wahl. *Orthis actoniæ*, Sow. *O. biloba*, Linn. *O. alternata*, Sow. *O. flabellulum*, Sow. *O. porcata*, M'Coy. *Strophomena simulans*, M'Coy. *S. pecten*, Linn. CŒLENTERATA.
S. AND S.E. OF CERRIG - Y - DRUIDION.	*Monticulipora* (*Nebulipora*) *favulosa.* *Favosites fibrosa*, Goldf. *F.*, var. *ramulosa*, Phill. *Monticulipora* (*Chætetes*) *petropolitana*, Pand. *Aulopora.* ANNELIDA. *Tentaculites anglicus*, Salt. *Cornulites serpularius*, Schloth. CYSTIDEA. *Glyptocystites.* ASTEROIDEA. *Protaster Salteri*, Forbes. CRUSTACEA. *Agnostus trinodus*, Salt. *Asaphus Powisii*, Murch. *A. radiatus*, Salt. *Calymene Blumenbachii*, var. *Caractaci*, Salt. *C. brevicapitata*, Salt. *Cheirurus juvenis*, Salt. *C. octolobatus*, M'Coy. *Cybele rugosa*, Portl. *C. verrucosa*, Dalm. *Encrinurus sexcostatus*, Salt. *Homalonotus bisulcatus*, Salt. *Illænus Bowmanii*, Salt. *I. Davisii*, Salt. *Lichas laxatus*, M'Coy. *L.*, sp. *Phacops apiculatus*, Salt. *P. conicopthalmus.* *Remopleurides*, sp. *Trinucleus concentricus*, Eaton. *T. seticornis*, His. *Beyrichia complicata*, Salt. (*Primitia*). *Primitia* (*Beyrichia*) *strangulata*, Salt.
S. AND S.E. OF CERRIG - Y - DRUIDION—*cont.*	BRYOZOA. *Fenestella subantiqua*, D'Orb. BRACHIOPODA. *Crania divaricata*, M'Coy. *Leptæna sericea*, Sow. *L. tenuicincta*, M'Coy. *Orthis actoniæ*, Sow. *O. alternata*, Sow. *O. flabellulum*, Sow. *O. biforata*, Schloth. *O. calligramma*, Dalm. *O. elegantula*, Dalm. *O. spiriferoides*, M'Coy. *O turgida*, M'Coy. *O. vespertilio*, Sow. *Rhynchonella*, sp. *Strophomena deltoidea*, Conrad. *S. expansa*, Sow. *S. rhomboidalis*, Wilck. LAMELLIBRANCHIATA. *Modiolopsis*, sp. GASTEROPODA. *Holopea concinna*, M'Coy. *Murchisonia simplex*, M'Coy. PTEROPODA. *Theca triangularis*, Portl. HETEROPODA. *Bellerophon carinatus*, Sow. CEPHALOPODA. *Lituites cornu-aristis*, Sow. *Orthoceras.*
S. OF LLANGOLLEN.	CŒLENTERATA. *Favosites Gothlandica*, Linn. *F. fibrosus*, Goldf. *Heliolites interstinctus*, Wahl. *Petaria sub-duplicata*, M'Coy. *P.*, sp. *Halysites catenularius*, Linn. *Omphyma turbinata*, Linn. *Aulopora.* CYSTIDEA. *Echinosphærites Davisii*, M'Coy. *Calymene Blumenbachii*, var. *Caractaci*, Salt. *Phacops apiculatus*, Salt. *Harpes Dorani*, Portl. BRYOZOA. *Ptilodictya explanata*, M'Coy. BRACHIOPODA. *Leptæna sericea*, Sow. *Lingula ovata*, M'Coy. *Orthis biforata*, Schloth. *O. calligramma*, Dalm. *O. elegantula*, Dalm. *O. porcata*, M'Coy. *O. testudinaria*, Dalm. *O. vespertilio*, Sow. *Strophomena rhomboidalis*, Wilck. *S. expansa*, Sow. *S. pecten*, Linn. GASTEROPODA. *Raphistoma.* *Trochonema.*

S. OF LLANGOLLEN—*cont.*	HETEROPODA. *Bellerophon bilobatus*, Sow. *B. dilatatus*, Sow. *B. nodosus*, Salt.	WREXHAM - -	*Favosites fibrosa*, Goldf. *Petraia sub-duplicata*, M'Coy. *Calymene brevicapitata*, Portl.
	CEPHALOPODA. *Cyrtoceras inæquiseptum*, Portl. *Lituites anguiformis*, Salt.	LLANGYNNOG (RUTHIN).	*Primitia (Beyrichia) complicata*, Salt. *Leperditia (Cythere) umbonata.*
CYRN-Y-BRAIN, WREXHAM.	CŒLENTERATA. *Favosites fibrosa*, Goldf. *Petraia subduplicata*, M'Coy. *P.*, sp.	PENTRE - CWM - DDU.	*Orthis alternata*, Sow.
		E. OF LLANELIDAN.	*Leptæna sericea*, Sow.
	CRUSTACEA. *Calymene brevicapitata*, Portl.	LANFUROG RUTHIN.	*Orthis elegantula*, Dalm. *Leperditia (Cythere) umbonata.*
	BRYOZOA. *Ptilodictya explanata*, M'Coy.	NANT-Y-BRAIN -	*Calymene brevicapitata*, Salt.
	BRACHIOPODA. *Orthis porcata*, M'Coy. *Orthisina adescendens*, Pand. *Strophomena deltoidea*, Con. *S. rhomboidalis*, Wilck.	CAPEL GARMON	*Homalonotus bisulcatus*, Salt. *H. rudis*, Salt. *Phacops alifrons*, Salt.
		CRICOR-MAWR -	*Leptæna sericea*, Sow.
		S. OF PONT-Y-GLYN.	*Leptæna sericea*, Sow.

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In examining these lists, a few observations are worth making on the grouping of the fossils; for example, the prevalence of one coral, the *Favosites (Stenopora) fibrosus*, and the presence of *Cystideæ* in notable quantity.

These last are confined to the very remarkable patch of blue-grey argillaceous limestone at Rhiwlas Farm, and its neighbourhood on the north-west side of Bala Lake, Merionethshire. Elsewhere the limestone has more or less of an arenaceous character, and it is the rarely that *Cystideæ* to occur in such a rock. But in the above-named locality they are found in plenty, and chiefly belong to two genera characteristic of Lower Silurian rocks, viz., *Sphæronites* and *Echinosphærites*. The former genus (pl. 20, Figs. 1–5) is covered with pores in irregular order, arranged in pairs. The other, as well shown by Von Buch and Ed. Forbes, is covered with numerous straight pore-canals, which striate the whole surface with a web-like ornament. *Hemicosmites* is a rarer form. The same groups of genera and species occur in similar beds, at one spot in South Wales, Shoal's Hook, near Haverfordwest, in Pembrokeshire.

The few starfishes quoted belong to genera now pretty well known to exist in Silurian strata. *Palæaster* is a common genus in the old rocks, but especially in the Caradoc. We have four species in England, and under the names *Palæaster* and *Stenaster* it is common in America. The other genus, *Protaster* (or *Tæniaster*,*) is frequent in Upper Silurian. The one here figured is the first starfish found in strata of this age in Britain, and was discovered by Professor Sedgwick and Mr. Salter in 1843, and named by Professor Forbes. The specimens were lost for years, but are now recovered from among Forbes's miscellanea, and both species are given in our plate.

Glyptocrinus basalis is the common crinoid of this formation; the scattered rings or osiculæ occur throughout the whole; they are very characteristic, and easily recognised by their hollow centre: there is no other determinable species,—though abundant fragments occur in the Bala limestone.

The annelide tubes figured in plate 14 are interesting only as showing the position occupied by the great worms that made them. They lie horizontally in the beds, with both ends raised a little, the annelide has risen successively with the layers of deposit, one tube rising above the other, so as to form a rough index of the time taken to accumulate the stratum. Annelide or worm burrows are abundant everywhere.

* Billings, in his excellent Canadian Decades, No. IV. *Arthraster* of the same work appears to be a *Palæaster*.

The curious little bivalve crustacea named *Beyrichia* by M'Coy, are abundant everywhere in Caradoc rocks, but are not strictly confined to them, occurring also in Llandeilo flags. *B. complicata* is the common form.

The Trilobites differ in species, as above said, according to the nature of the sea bottom. In the pale grey deep-water Bala limestone at Rhiwlas, Bala, we find—

Trinucleus seticornis, Hisinger.
Ampyx tumidus, Forbes.
Illænus Davisii, Salter.
Agnostus trinodus, Salter.
Cheirurus bimucronatus, Murch. (*C. octolobatus*, M'Coy.)
Asaphus radiatus, Salter.

With many others.

In the sandstone beds above and below, and in the actual Bala limestone, where it is of a sandy character, we have—

Trinucleus concentricus, Eaton.
Illænus Bowmanni, Salter.
Asaphus Powisii, Murchison.
Calymene Blumenbachii, var. *brevicapitata*, Portl.
Phacops apiculatus, Salter.

And this arrangement appears constant, for in other localities remote from Bala, where the same conditions of depth and bottom appear to have prevailed, the limestone species occur in *calcareous* slate, and the common sand-loving species are absent. Where the conditions are reversed, the fauna alters once more. It is so with the Brachiopoda. In the argillaceous limestone *Leptæna 5-costata* is plentiful; in the Sandstone *L. sericea*. *Strophomena expansa* is the universal fossil where sand has prevailed; it is not found in limestone—*S. alternata* takes its place here. *Strophomena tenuistriata* is a sparsely distributed fossil everywhere; and *S. Rhomboidalis* is very common in beds of all characters. *Orthis vespertilio* affects sandy limestone, and with *O. Actoniæ* and *O. biforata* appears not to have flourished well in other matrices; but *O. calligramma*, though able to live in most deposits, appears to have had a special liking for coarse sand and conglomerates, where it often grew to a large size, to the exclusion of other species. A due admixture of sand and calcareous matter, however, appears to have best suited nearly all the species, which then grew or lived in the greatest numbers and of the largest size. One of the best localities to study the stratigraphical arrangement of the Brachiopoda is the precipitous ground round Lake Ogwen. The map shows several beds of trap. Between these we have beds, with specimens of *Leptæna sericea* an inch wide! and of *Orthis elegantula* fully half an inch in diameter. The *Leptæna 5-costata* and *L. tenuicincta* occur only in calcareous or argillaceous beds; and these are common but rather small shells, not generally known. *Lingula* is not common. One species, *L. ovata*, seems to be peculiar to the Bala limestone. Further eastward, one of the largest *Lingulæ* known is plentiful on the same horizon, *L. tenuigranulata*, M'Coy.

Of the Lamellibranchs but little can be said, so many imperfect specimens remain to be described; and these are of species or genera identical with those of foreign Caradoc strata,—the genera *Orthonota*, *Cyrtodonta* (Billings), (*Palæarca* (Hall)), and *Modiolopsis*, with a few *Pterineæ*, being the principal forms. *Ctenodonta varicosa*, a small triangular nuculoid shell, seems to occur in great plenty at various spots, *e.g.*, near Conway Falls, and along the line of hills west of Bala Lake. The *Ambonychia carinata* of Conrad is one of the many species which help to link the British and American Caradoc rocks together.

Murchisonia, *Raphistoma*, *Holopella*, and *Holopea* are the common univalve shells. Of the last, three or four species occur in a group together in the Bala limestone at Rhiwlas. Perhaps the *Cyclonema crebristria*, M'Coy, is the most common univalve of all, and it is one which occasionally ranges up into the Llandovery rocks.

Of the Pteropoda (*Theca reversa*, woodcut 14), one species is very common, and differs from Upper Silurian forms in having the opposite side convex to that which is usually so in the genus. It appears to be an equally common species on the other side of the Atlantic. *Pterotheca* (woodcut 18) is

a much rarer form; it is wider and more expanded than any living shell of the group, and unlike Pteropods in general. An unfigured species, *P. undulata*, occurs in tolerable plenty in the yellowish shaley beds in Caernarvonshire. It is a singular fossil. But both the Pteropoda and Heteropoda appear to have been larger, heavier-shelled, and altogether of more extraordinary forms in Silurian times than they have ever been since.

Lastly, among the Cephalopoda are some large and curious forms of *Cyrtoceras*. This genus is remarkable for the variety of positions in which its siphuncle is placed,—sometimes on the dorsal, sometimes the ventral margin, and in every conceivable position between these two points.*

The small *Lituites* or *Trocholites planorbiformis* of our list is in the Woodwardian collection. It is not the only lituite-formed shell, for the *L. cornu-arietis* occurs with it near Bala. But the group is singularly rare in the Welch district, though so common both in Sweden and America.

These genera are only found at Rhiwlas, Bala, in the argillaceous limestone before noted; and the common *Orthoceratite* with them is the *O. vagans* (Salter), a species having wide distribution, since it ranges at least as far as Portugal. It abounds in the Bala limestone in one or two localities. (*See* plates 24 and 25.)

In this same limestone some curious phosphatic nodules were obtained, which were analysed by Dr. Playfair, and found to contain over 30 per cent. of phosphate.† Mr. Sterry Hunt had not at that time printed his valuable observations on the phosphates derived from molluscous remains in the still older beds of Canada. It was at the time thought probable that fish had left their coprolite exuviæ in this locality; but the progress of research has shown that every one of the supposed fish remains in this or any other country, on a lower horizon than that of the Ludlow rocks, may be referred properly to other and inferior classes of animals.‡

Lower Llandovery Rocks.

As described in the Memoir, certain sandstones and conglomerates of this age, not separated from the Lower Silurian rocks at the time the maps were made, range into the district. They are but ill represented, however, in cabinets of fossils, and except in the Meifod and Welshpool districts, have not been noticed in the Memoirs of Professor Sedgwick. The chief locality for these strata is the limestone and conglomerate described by him (as Bala beds, not as of Llandovery age) at Pen-y-craig and Mathyrafal, on the banks of the Vyrnwy, south-west of Meifod.§ But the Rev. Dr. Cumming found fossils on the ridges below Guilsfield, near Welshpool, which truly belong to this age.‖ The *Cefn*, 3 miles north-east of Welshpool, near Buttington, has a small patch of these rocks coloured Lower Silurian; and they occur among the Breidden Hills, according to the investigations of Forbes, who did not, however, bring fossils home. It may here be said for those species quoted in our foot-note, from the two localities, Cyrn-y-brain, W. of Wrexham, and Pwllheli, Caernarvonshire, that the Geological Survey is not responsible for the localities, nor Professor M'Coy for the formations. The lists so carefully made out by him from Professor Sedgwick's collections accurately represent those collections. There is no reasonable doubt of the occurrence of Lower Llandovery fossils on the outlier of Cyrn-y-brain; but it may well be doubted whether there be not some mistake as to the locality from which the so-called Pwllheli fossils were obtained. So far as we know, no patches of Middle Silurian occur all over the country west of the Snowdon chain, nor indeed for some distance east and south of it. On the other hand, if the *Pentameri*, and the Trilobites and shells quoted in the annexed list (taken from the Cambridge

* The position of the siphon in the two great groups *Nautilidæ* and *Ammonitidæ* is remarkably constant, while *Cyrtoceras*, occurring as it does in older rocks than either, seems to combine both types. In *Orthoceras* it is variable, but not much so in any of the involute genera.

† Quart. Journ. Geol. Soc., vol. 7, 1851.

‡ *See* note by J. W. S. in Hugh Miller's "Footprints of the Creator," 2nd edit., by M' p. 315.

§ Quart. Journ. Geol. Soc., 1845, vol. i., p. 20. Quoted also by Prof. Ramsay, vol. ix

‖ It is probable that the Lower Llandovery beds sweep round the edge of the Wer in many places. We can, however, only give known localities for fossils.

Synopsis), were really obtained from near Pwllheli,* it is certain that the Llandovery rocks exist there.

It would be well to search the boundary rocks around the edge of the Wenlock formation. Should we not find these Lower Llandovery beds, characterised by the numerous *Petraiæ* and *Pentameri*,† we shall at least be working among the richest beds of the Caradoc formation, where the species are most abundant. A pale-coloured slate (Tarranon shale), which, when collecting with Professor Sedgwick, we used to term "pasty rock," and which ranges all through the Meifod and Llanfyllyn country, might well be a portion of the Lower Llandovery series, as it is rich in corals. But the characteristic *Pentameri* were never found in it by us, the survey, or by other observers.

The list of species is as follows, including all those quoted by Professor M'Coy, as the majority of the specimens were collected by Mr. Salter in company with Professor Sedgwick. Professor M'Coy's name is attached to those not seen by Mr. Salter.

Localities for Lower Llandovery Fossils in South Wales.

CAERMARTHENSHIRE.

Pen-y-Craig -	Cœlenterata. *Petraia uniserialis*, M'Coy. *Favosites aspera*, D'Orb. *Halysites catenularius*, Linn. Hydrozoa. *Ptilodictya explanata*, M'Coy. *P. lanceolata*, Goldf. *Monograptus priodon*, Bronn.	Pen-y-Craig—*cont.*	Brachiopoda. *Rhynchonella subundata*, M'Coy. *Orthis biforata*, Schloth. *O. turgida*, M'Coy. *O. actoniæ*, Sow. *O. elegantula*, Dalm. *O. lata.* *O. insularis*, Eichw. *Pentamerus globosus.* *Strophomena antiquata*, Sow. Crustacea. *Trinucleus concentricus*, Eaton.

MONTGOMERYSHIRE.

Llangyniew -	Cœlenterata. *Petraia uniserialis*, M'Coy. *Favosites aspera*, D'Orb. *Halysites catenularius*, Linn. Hydrozoa. *Monograptus priodon*, Bronn. Crustacea. *Trinucleus concentricus*, Eaton. Bryozoa. *Ptilodictya explanata*, M'Coy. *P. lanceolata*, Goldf. Brachiopoda. *Leptæna transversalis*, Wahl. *Strophomena antiquata*, Sow.	Mathyrafal -	Cœlenterata. *Petraia uniserialis*, M'Coy. *Favosites fibrosa*, Goldf. *Heleolites megastoma*, M'Coy. *H. interstincta.* *Favosites aspera*, D'Orb. *Halysites catenularius*, Linn. *Omphyma turbinata*, Linn. Crustacea. *Calymene Blumenbachii*, Brong. *C.*, var. *Caractaci*, Salt. *Encrinurus punctatus*, Brünn. *Beyrichia complicata*, Sow. Bryozoa. *Ptilodictya costellata*, M'Coy.

* The species in question are:

All from Pwllheli, Caernarvonshire, according to the Cambridge Synopsis.

- *Encrinurus punctatus* - -
- *Rhynchonella* 10-*plicata* (*diodonta*, M'Coy)
- *R. hemisphærica* - - - -
- *Rhynchonella upsilon* - -
- *Pentamerus lævis* - - - -
- *Strophomena compressa* - - -

These are all mentioned by M'Coy, and are certainly Llandovery species. The Cyrn-y-brain species are inserted in the general list, p. 58 of the Synopsis.

† The genus *Nidulites* should be looked for, *see* Siluria, 2nd edit., p. 203, Foss. 27, fig. 3. It is a common and characteristic Lower Llandovery fossil.

MATHRAFAL—*cont.*	*Fenestella sub-antiqua*, D'Orb. BRACHIOPODA. *Leptæna transversalis*, var. *undulata*, Wahl. *L. sericea*, Sow. *Rhynchonella.* *R. subundata*, M'Coy. *Atrypa reticularis*, Linn. *Strophomena rhomboidalis*, Wilck. *S. antiquata*, Sow. *S. expansa*, Sow. *Orthis biforata*, Schloth. *O. turgida.* *O. actoniæ*, Sow. *O. elegantula*, Dalm. *O. insularis*, Eichw. *Pentamerus undatus.* *P. globosus.* *P. (Stricklandinia) lens.*	CEFN, NEAR BUTTINGTON.	CÆLENTERATA. *Petraia uniserialis*, M'Coy. *P. subduplicata*, M'Coy. *Favosites fibrosa*, D'Orb. *Halysites catenularius*, Linn. *Omphyma turbinata*, Linn. CRUSTACEA. *Calymene Blumenbachii*, Brong. BRACHIOPODA. *Atrypa reticularis*, Linn. *Strophomena rhomboidalis.* *Pentamerus (Stricklandinia) lens.* *P. oblongus.*
		MEIFOD - -	*Discina.* *Petraia uniserialis*, M'Coy.

PEMBROKESHIRE.

QUAKERS' BURIAL GROUND.	*Favosites (Stenopora) fibrosa*, D'Orb.	QUAKERS' BURIAL GROUND —*cont.*	BRACHIOPODA. *Atrypa reticularis*, Linn. *Strophomena euglypha.* *S. rhomboidalis, Wilck.* *Pentamerus undatus.* *Spirifera plicatella.*

LOWER LLANDOVERY FOSSILS.

In addition to the above, I have prepared a complete list of all the species known in the Lower Llandovery rocks of North Wales, South Wales, Scotland, and Ireland, thus bringing together all that is known of the distribution of life through this middle period of Silurian time. This table and the one devoted to Upper Llandovery life I conceive to be of great value, as tending to show the relation of this transitional group between the Lower Silurian and well-defined Wenlock and Ludlow series. Careful analysis shows that 204 species occur in the Lower Llandovery beds of Great Britain and Ireland. The chief groups of life are the Hydrozoa, Actinozoa, Crustacea, Brachiopoda, and Gasteropoda, which together make up 176 species out of the 204.

The Actinozoa number 25 species, out of which the genus *Favosites* is illustrated by 5 species, *Heliolites* 4, and *Petraia* 6, the remaining 9 genera having 1 species in each. The Crustacea number 12 genera and 25 species, 6 of which are North Welsh forms, and 6 South Welsh; the remainder Irish and Scotch. The genera *Calymene*, *Illænus*, and *Phacops* are the richest in species.

The 59 species in the Brachiopoda chiefly illustrate 5 genera, *Atrypa* having 6 species, *Leptæna* 4, *Orthis* 20, *Rhynchonella* 7, and *Strophomena* 11. The species of Gasteropoda number 16, and *Orthoceras* 8. It is important to also compare the Caradoc fauna with that of the Lower Llandovery, when it will be found that no less than 103 Caradoc species are common to the Lower Llandovery, which possesses 204 species. Fifteen of the 20 known Actinozoa are common, 5 of the 12 Crustacea, all the Hydrozoa. Of the 59 Brachiopoda, 37 are Caradoc, 16 species of Gasteropoda are known in the Lower Llandovery, and 9 others are also Caradoc, and with one exception all the Cephalopoda and Heteropoda are common. Again, the still larger Upper Llandovery fauna, numbering 240 species, contains 60 Caradoc forms, and 104 pass up from the Lower Llandovery into the Upper or May Hill Sandstone group.

Further analysis shows that in North Wales there are 43 species, and South Wales 119, of which only 17 are common to the two areas. Scotland has yielded 127 species, and Ireland 195. The four South Wales counties I have stated yield 152 species, and they are distributed in the following manner:—

Areas.	Species.	Protozoa.	Hydrozoa.	Actinozoa.	Echinodermata.	Annelida.	Crustacea.	Bryozoa.	Brachiopoda.	Lamellibranchiata.	Gasteropoda.	Heteropoda, &c.	Cephalopoda.
Cardiganshire -	13	—	—	1	1	—	1	—	10	—	—	—	—
Caermarthenshire	62	—	1	10	—	1	2	2	35	2	5	2	2
Pembrokeshire -	45	1	—	8	1	1	6	—	22	—	3	1	—
Radnorshire -	32	—	—	4	—	1	2	—	19	—	2	2	1
	152	1	1	23	2	3	11	2	86	2	10	5	3

Distribution of the Lower Llandovery Fossils.

Occur in and Pass up.		Lower Llandovery Species.	Localities.							Counties.						
			North Wales.				South Wales.			South Wales.						
Llandeilo.	Caradoc.		Pen Craig.	Mathrafal.	Llangyniew.	Cefn Buttington.	Llandovery.*	Haverfordwest.	Llandeilo (Blaen-y-cwm).	Cardiganshire.	Carmarthenshire.	Pembrokeshire.	Radnorshire.	Scotland.†	Ireland.	Upper Llandovery.
		PROTOZOA.														
	×	*Acanthaspongia Siluriensis*, M'Coy.						×				×				
	×	*Nidulites favus* -						×			×	×		×		
		Stromatopora striatella. D'Orb.						×				×				
		HYDROZOA.‡												60		

* Noeth Grug, near Llandovery. Gorllwyn-fach, near Llandovery.
Maudinam, „ Golen-goed „
Cel-Gwyn „

† The well-marked and well-determined *Graptolite* fauna of the Moffat group (Birkhill division) in Scotland, which probably might be correlated with the Lower Llandovery rocks of Wales and Shropshire, cannot be recognized here; they stand alone as a well-defined northern group, worked out with great accuracy by Lapworth. *Vide* Geol. Mag., Vol. 3, Dec. II., pp. 308–319, 350–360, 499–507, 544–552, and Quart. Journ. Geol. Soc., Vol. 34, pp. 240–346. Possibly the coal pit bay species in county Down, Ireland, are of Llandovery age. In Wales few species occur in the Llandovery beds, and therefore cannot be compared here, but Mr. Lapworth names nearly 60 species from the Birkhill shales, none of which I add to the above table; they would be out of place here.

Professor Walter Keeping has carefully investigated the Geology of Central Wales, and in a valuable paper communicated to the Geological Society [Quart. Journ. Geol. Soc., Vol. xxxvii., pp. 141–170] has added greatly to our knowledge of this hitherto little known region. Prof. Lapworth in an appendix to the paper has described the Cladophora or Dendroid Graptolites collected by Mr. Keeping from the Lower Llandovery rocks of Cardiganshire; the forms described as a whole Mr. Lapworth regards as a type almost new to British Palæontology; they are essentially of a Upper Silurian facies resembling the "Clinton and Niagara Group of New York and Upper Canada." Four genera and seven species are described by Mr. Lapworth. The genera are Dictyonema, Calyptograptus, Acanthograptus, and Odontocaulis, the three last named are new to Britain, and of the seven species four are, according to Mr. Lapworth, peculiar to the Mid Wales area, they are Dictyonema corrugatellum, Calygraptus plumosus, C. digitatus, and Odontocaulis Keepingii. Mr. Keeping's paper has filled a great want in the history of the Welsh Middle Silurian rocks, and for the first time we have a general succession of the rocks of the "Aberystwyth, Metalliferous, and Plynlimmon Groups," and the Plynlimmon Anticlinal. The Aberystwyth grits contain numerous Graptolites (Monograpti). The Metalliferous Slate Group of the Devil's Bridge is rich in fossils. Monograptus three species, Dictyonema two, Calyptograptus one, Rhizograptus two, Odontocaulis one; also Annelide tracks. Morben and Cwm Symlog are important fossil-bearing localities in the Metalliferous Slate Group. No less than 12 species of Monograpti occurring. The third or Plynlimmon Group is unfossilliferous, but is over 1,000 feet thick. The true succession, however, of the entire Mid-Wales series can only be determined through the study of organic remains. Mr. Keeping enumerates 42 species occurring in the two groups, viz., the Aberystwyth Grits and the Metalliferous Slates.

R. E.

Occur in and Pass up.		Lower Llandovery Species.	Localities.							Counties.						
			North Wales.				South Wales.			South Wales.						
Llandeilo.	Caradoc.		Pen Craig.	Mathrafal.	Llangyniew.	Cefn Buttington.	Llandovery.	Haverfordwest.	Llandeilo (Blaen-y-cwm).	Cardiganshire.	Carmarthenshire.	Pembrokeshire.	Radnorshire.	Scotland.	Ireland.	Upper Llandovery.
		ACTINOZOA.														
	×	*Aulacophyllum mitratum*, His.			?									×		?
	×	*Cyathophyllum articulatum*, Wahl.												×	×	
		C. angustum, Lonsd. -														
		Cystiphyllum cylindricum, Lonsd.													×	
	×	*Favosites aspera*, D'Orb.					×	×			×	×		×		×
	×	*F. fibrosa*, Goldf. -	×	×	×		×	×		×		×	×	×	×	?
	×	*F. gothlandica*, Linn.					×					×		×	×	×
	×	*F. lycoperdon*, Hall -					×					×				
	×	*F. multipora*, Lonsd.	×	×								×		×	×	×
	×	*Halysites catenulatus*, Linn.	×	×	×	×	×		×			×	×		×	×
	×	*Heliolites favosus*, M'Coy (Lyopora).												×		×
	×	*H. interstinctus*, Linn.		×			×	×				×		×	×	×
	×	*H. megastoma*, M'Coy		×				×				×		×	×	×
	×	*H. tubulatus*, Lonsd.										×		×	×	×
	×	*Monticulipora explanata*, M'Coy.						×								
	×	*Omphyma turbinata*, Linn.		×		×						×		×	×	×
		Palæocylus porpita, Linn.														×
		P. præacutus, Lonsd.						×								×
	×	*Petraia bina*, Lonsd.										×		×	×	×
	×	*P. elongata*, M'Coy -											×			×
	×	*P. rugosa*, Phill. -										×				×
	×	*P. subduplicata*, M'Coy		×	×	×		×				×	×	×	×	×
	×	*P. uniserialis*, M'Coy	×	×	×	×						×		×	×	×
		P. zizac, M'Coy -														×
	×	*Plasmopora petalliformis*, Lonsd.										×				×
		Syringopora Lonsdaleiana, M'Coy.													×	×
		Pinacopora grayi, N. & E.												×		
		ECHINODERMATA.														
	×	*Echinosphærites arachnoidea*, Forbes.											×			
	×	*Glyptocrinus*, stem rings (many places).					×	×		×		×	×	×		
		ANNELIDA.														
	×	*Cornulites serpularius*, Schloth.											×			×
	×	*Tentaculites anglicus*, Salt.						×			×	×			×	×
		T. ornatus, Sow. -												×		
		CRUSTACEA.														
		Proetus girvanensis, Ether.												×		
		P. Procerus, Ether. -												×		
×	×	*Calymene Blumenbachii*, Brong.		×		×		×	×	×	×	×	×	×	×	×
	×	*C. allportiana*, Salt. -									×	×	×	×	×	
	×	*C. caractaci*, ? Salt. -		×												
	×	*C. brevicanitata*, Porte		×												×
	×	*Encrinurus punctatus*, Brünn.		×									×	×	×	×
	×	*Beyrichia complicata*		×												
	×	*B. Kieslenii*, M'Coy -												×		

Occur in and Pass up.		Lower Llandovery Species.	Localities.								Counties.						
			North Wales.				South Wales.				South Wales.						
Llandeilo.	Caradoc.		Pen Craig.	Mathrafal.	Llangyniew.	Cefn Buttington.	Llandovery.	Haverfordwest.	Llandeilo (Blaen-y-cwm).		Cardiganshire.	Carmarthenshire.	Pembrokeshire.	Radnorshire.	Scotland.	Ireland.	Upper Llandovery.
		CRUSTACEA—*cont.*															
×	×	*Illænus Bowmanni*, Salt.					×	×				×	×		×	×	×
	×	*I. Thomsoni*, Salt. -													×		×
		I. Macallumi, Salt. -													×		×
	×	*I. nexilis*, Salt. - -													×		×
	×	*Cheirurus bimucronatus*, Murch.					×								×	×	×
		Acidaspis Brightii -						×					×		×	×	×
		Phacops Stokesii -															
	×	*P. Brongniarti*, Portl.													×		
	×	*P. subduplicatus*, Salt.						×					×				
		P. sublævis? M'Coy -														×	
	×	*Trinucleus concentricus*, Eaton.	×		×								×				
		T. fimbriatus? Murch.													×	×	×
	×	*Cyphaspis megalops*, M'Coy.													×		
	×	*Lichas Barrandei*, Flet.													×		
		L. grayii, Flet. -													×		
		L. Geikiei, Ether. -													×		
		L. laxatus? - -					×								×		×
		Discinocaris Browniana, Woodw.													×	×	
		BRYOZOA.															
	×	*Fenestella subantiqua*, D'Orb.		×								×	×				×
	×	*Ptilodictya costellata* P. *explanata*, M'Coy.		×													
	×	*P. lanceolata*, Goldf.	×	×	×		×										
	×	*P. dichotoma*, Portl. -			×						×	×	?		×	×	×
		BRACHIOPODA.															
		Atrypa hemisphærica, Sow.											×	×	×	×	×
	×	*A. imbricata*, Sow. -															
	×	*A. marginalis*, Dalm.		×	×	×	×	×			×	×	×	×	×	×	×
		A. reticularis, Linn.		×		×	×	×	×		×	×	×	×	×	×	×
		A. scotica, M'Coy -				×	×	×									
		Crania implicata, Sow.					×					×				×	×
	×	*Leptæna quinquecastata*, M'Coy.		×	×		×					×			×	×	×
	×	*L. scissa*, Sow. - -					×	×				×	×				×
	×	*L. sericea*, Sow.- -		×			×	×			×	×					×
	×	*L. transversalis*, Wahl.	×	×	×		×	×	×		×	×	×	×	×	×	×
	×	*Meristella angustifrons*, M'Coy.					×					×		×	×	×	×
	×	*M. crassa*, Sow.- -		×			×	×			×	×	×	×			×
		M. subundata, M'Coy		×	×												
×	×	*Orthis Actoniæ*, Sow.	×	×				×				×	×			×	
×	×	*O. biforata*, Schloth.	×	×	×		×					×					
	×	*O. biloba*, Linn. -					×	×				×	×				
		O. Bouchardi - -					×					×					
×	×	*O. Calligramma*, Dalm.					×	×	×		×	×	×	×			
	×	*O. Wallsallensis*, Dav.						×					×				
×	×	*O. confinis*, Salt. -										?					
	×	*O. crispa*, M'Coy -										×					
	×	*O. elegantula*, Dalm.-	×	×			×		×		×	×	×	×			
	×	*O. fallax*, Salt. - -													×		
	×	*O. insularis*, Eichw.-		×			×					×					
	×	*O. porcata*, M'Coy -					×	×	×			×	×				
	×	*O. protensa*, Sow. -		×			×						×				
		O. reversa, Salt.- -		×			×							×	×	×	
		O. Mullockensis, Dav.													×		
	×	*O. sagittifera*, M'Coy													×	×	×
	×	*O. testudinaria*, Dalm.		×			×					×				×	×

Occur in and Pass up.		Lower Llandovery Species.	Localities.								Counties.						
			North Wales.				South Wales.				South Wales.						
Llandeilo.	Caradoc.		Pen Craig.	Mathrafal.	Llangyniew.	Cefn Buttington.	Llandovery.	Haverfordwest.	Llandeilo (Blaen-y-cwm).		Cardiganshire.	Carmarthenshire.	Pembrokeshire.	Radnorshire.	Scotland.	Ireland.	Upper Llandovery.
		BRACHIOPODA—*cont.*															
	×	*O. tricenaria*, Con. -													×		
×	×	*O. turgida*, M'Coy -	×	×													
×	×	*O. Vespertilio*, Sow. -										×					
		Pentamerus globosus, Sow.	×	×			×					×				×	×
		P. oblongus, Sow. -				×						×			×	×	×
		P. undatus, Sow. -	×	×	×		×	×			×	×	×	×		×	×
	×	*Rhynchonella borealis*, Schloth.						×					×			×	×
		R. Llandoveryana, Dav.					×			×		×	×		×	×	×
		R. cuneata, Dalm. -													×		×
	×	*R. nasuta*, M'Coy -										×			×		
		R. nucula, Sow. - -													×		×
	×	*R. subundata*, M'Coy	×	×													
		R. tripartita, Sow. -					×					×					×
		Spirifera plicatella, Linn.						×					×	×	×	×	×
		S. var. *radiata*, Sow. -												×			×
		S. exporrecta - -										×		×		×	
		Stricklandinia lens, Sow.		×		×	×	×				×	×	×	×		×
		S. lirata, Sow. - -					×					×				×	×
	×	*Strophomena attenuata*.						×				×	×	×			×
		S. arenacea, Salt. -						×				×	×	×			
	×	*S. antiquata*, Sow. -	×	×	×			×	×			×	×	×			×
		S. applanata, Salt. -									×					×	×
		S. compressa, ? Sow. -						×					×	×		×	×
	×	*S. corrugatella*, Dav.										×			×	×	
		S. euglypha, His. -						×	×			×	×	×	×	×	
	×	*S. expansa*, Sow. -		×								×					
	×	*S. rhomboidalis*, Wilck.		×		×		×	×			×	×	×	×	×	×
	×	*S. pecten*, Linn. -										×			×	×	×
	×	*S. alternata*, Con. -					×										×
		LAMELLIBRANCHIATA.															
		Pterinæa retroflexa, Wahl.										×				×	×
	×	*Mytilus Mytilimeris*, Conrad.										×					×
	×	*Orthonota sulcata*, His.										×					
		Megalomus, sp.					×										
		GASTEROPODA.															
		Acroculia Haliotis, Sow.													×	×	×
	×	*Cyclonema crebristria*, M'Coy.						×	×			×	×	×		×	×
	×	*Holonella cancellata*, Sow.										×					×
	×	*H. tenuicincta*, M'Coy							×						×	?	×
	×	*Murchisonia angulata*, Sow.					×	×					×				
	×	*M. cancellata*, M'Coy						×					×		×	?	
	×	*M. gyrogonia*, M'Coy							×					×			
		M. Pryceæ, Sow. -					×		×			×					
	×	*M. pulchra*, M'Coy -		×												×	
		M. sulcata, M'Coy -														×	×
		Platyschisma Williamsii, Sow.										×	×				
	×	*Pleurotomaria Moorei*, Salt.													×		
	×	*Raphistoma lenticularis*, Sow.										×			×	×	
	×	*Trochonema trochleata*, M'Coy.														×	×
		Trochus Moorei, M'Coy															×
		T. multitorquatus, M'Coy.													×	?	×

Occur in and Pass up.		Lower Llandovery Species.	Localities.							Counties.						
			North Wales.				South Wales.			South Wales.						
Llandeilo.	Caradoc.		Pen Craig.	Mathrafal.	Llangynicw.	Cefn Buttington.	Llandovery.	Haverfordwest.	Llandeilo (Blaen-y-cwm).	Cardiganshire.	Carmarthenshire.	Pembrokeshire.	Radnorshire.	Scotland.	Ireland.	Upper Llandovery.
		PTEROPODA, &c.														
	×	*Conularia Sowerbyi*, Def.						×			×	×		×		?
		HETEROPODA.														
	×	*Bellerophon carinatus*, Sow.					×						×			×
×	×	*B. bilobatus*, Sow. -							×					×		×
		B. dilatatus, Sow. -					×		×		×		×		×	
		CEPHALOPODA.														
	×	*Lituites cornu-arietis*, Sow.					×								×	×
	?	*L. undosus*, Sow. -					×		×			×				
	×	*Orthoceras annulatum*, Sow.					×						×			×
	×	*O. ibex*, Sow. - -						×			×				×	×
	×	*O. politum*, M'Coy -												×		×
	×	*O. tenuistriatum*, Münst.					×	×						×		×
	×	*O. vagans*, ? Salt. -														
		Trotoceras bisiphonatum, Sow.					×				×					

NOTE.—The fine series of *Graptolitidæ* described by C. Lapworth, Esq., from the Birkhill beds of the Moffat series, and the Coniston mudstones of Westmoreland are not quoted here; they would be out of place in the North Welsh Memoir, unless the same species occurred in the Welsh Llandovery beds for comparison. *Vide* Quart. Journ. Geol. Soc., 1878, for Mr. Lapworth's exhaustive paper; also, A.M.N.H. vol. 5, fifth series, 1880, for distribution of the Llandovery Rhabdophora, in N. Wales, the Lake District, Scotland, and Ireland.

R.E.

LIST of WELSH LOWER LLANDOVERY FOSSILS, compiled chiefly from the Synopsis Brit. Pal. Rocks, Sedgwick and M'Coy, pp. 351–374.

Name.	Locality.
Petraia uniserialis, M'Coy - -	Pen-y-craig, Llangynyw (M'Coy); Mathyrafal; Meifod; Cefn, near Buttington.
P. subduplicata, M'Coy - -	Cefn, near Buttington.
Favosites fibrosa, Goldfuss. -	Mathyrafal; Quakers' Burying Ground.
Heliolites megastoma, M'Coy -	Do. (M'Coy).
H. interstincta, id. - -	Do.
Favosites alveolaris, Goldfuss. -	Mathyrafal; Pen-y-craig, Llangynyw (M'Coy); Cefn, near Buttington.
Halysites catenularius, Linn. -	Cefn, near Buttington; Mathyrafal (M'Coy); Pen-y-craig, near Llangynyw.
Omphyma turbinata, Linn. -	Mathyrafal; Cefn, near Buttington.
Trinucleus concentricus, Eaton -	Pen-y-craig, Llangynyw (M'Coy).
Calymene Blumenbachii, Brong. -	Cefn, near Buttington.
— var. *Caractaci* - -	Mathyrafal (M'Coy).
Encrinurus punctatus, Brünn. -	Mathyrafal.
Beyrichia complicata, Salter -	Do.
Ptilodictya costellata, M'Coy -	Do.
P. explanata, M'Coy - -	Mathyrafal; Pen-y-craig, Llangynyw.
P. lanceolata, Lons. - -	Pen-y-craig, Llangynyw.
Fenestella subantiqua, D'Orb. -	Mathyrafal.

Name.	Locality.
Monograptus priodon, Bronn. - -	Pen-y-craig, Llangynyw; Cefn Grugos, W. of Llanfyllin.
Leptæna transversalis, Dalm., var. *undulata*.	Mathyrafal; Pen-y-craig, Llangynyw.
L. sericea, Sow. - - - -	Mathyrafal (M'Coy).
Rhynchonella Lewisii, Dav. -	Mathyrafal.
R. subundata, M'Coy - - -	Mathyrafal and Pen-y-craig (M'Coy).
Atrypa reticularis, Linn., and - - *A. marginalis*, Dalm. - - -	Cefn, near Buttington; Quakers' Burying Ground; Mathyrafal.
Strophomena euglypha, Dalm. -	Quakers' Burying Ground.
S. rhomboidalis, Dalm. - - -	Quakers' Burying Ground; Cefn, near Buttington; Mathyrafal (M'Coy).
S. antiquata, Sow. β - - -	Mathyrafal; Pen-y-craig, Llangynyw.
S. grandis ? Sow. - - -	Mathyrafal (M'Coy).
S. expansa ? Sow. - - -	Do.
Orthis biforata, Schl. - - -	Mathyrafal and Pen-y-craig.
O. turgida, M'Coy - - -	Do.
O. Actoniæ, Sow. - - -	Do.
O. hybrida ? Sow. - - -	Do.
O. elegantula, Dalm. - - -	Do.
O. lata, Sow., var. *protensa* - -	Do.
O. insularis, Eichw. - - -	Do.
Pentamerus undatus, Sow. - -	Quakers' Burying Ground; Mathyrafal.
P. globos, Sow. - - - -	Pen-y-craig; near Meifod; Mathyrafal.
P. lævis, Sow. (young of *P. oblongus*) -	Cefn, near Buttington; Cryn-y-brain; Wrexham.
P. Stricklandinia lens, Sow. - -	Cefn, near Buttingon; Mathyrafal.
Spirifera plicatella, Linn. - -	Quakers' Burying Ground.
Spirifera percrassa (*Atrypa* ? Sil. Syst.)	Cyrn-y-brain; Mathyrafal.
Discina, sp. - - - -	Quakers' Burying Ground.

Upper Landovery Rocks (May Hill Group, Sedgwick).

Although the Upper Llandovery rocks have not been observed by the Geological Survey in North Wales, it is well to give a conspectus of the species found in South Wales, Shropshire, and other districts, in order to complete our view of the Silurian formations, of which a sketch for all Wales and Shropshire has been given in Chapters I. and II. Professor Hughes considers it probable that rocks of Llandovery age occur in Anglesea. He has enumerated 13 species from Treiorweth, which were collected by Mr. Henslow many years since, and now in the Woodwardian Museum, Cambridge, this may require further confirmation; there appears to be an ascending section of deposits from Llanerchymedd towards the north from the Tremadoc to the Caradoc, *see* Quart. Journ. Geol. Soc., vol. 36, 1880.

Upper Llandovery.

The number of known species occurring or known to occur in the Upper Llandovery or May Hill sandstone is 246.

The chief groups are the Actinozoa (32 species), Crustacea (24), Brachiopoda (65), Lamellibranchiata (29), Gasteropoda (28). The Heteropoda and Cephalopoda are represented by 11 and 19 species respectively.

The table is constructed to show the distribution of the Upper Llandovery species through the counties or chief areas in South Wales, viz., Pembrokeshire, Caermarthenshire, Cardiganshire, and Radnorshire; and Gloucestershire, Worcestershire, and Shropshire in England.

Four localities in South Wales, two in Gloucestershire, one in Worcestershire, and five in Shropshire sum up those areas where the Upper Llandovery species are known and distributed. 105 species are known and distributed through South Wales generally: 67 occur at Llandovery, 18 at Builth, 31 at Presteign, 28 at Marloes Bay. May Hill and Tortworth in Gloucestershire yield 64 species; at May Hill 52 species occur, and Tortworth 40. In Worcestershire (the Malvern area) 89 species, Shropshire five localities, the total distribution being 90 species; but 18 occur in the Onny river beds, 33 at Norbury, 28 at Chirbury, 30 at Church Stretton, and 46 at Bog Mine.

Caradoc.	Lower Llandovery.	Upper Llandovery or May Hill Sandstone Species.	Localities. South Wales. 1. Llandovery.	2. Builth.	3. Presteign.	4. Marloes Bay.	Gloucestershire. 5. May Hill and Huntley.	Worcest. 6. Tortworth.	7. Malvern Area.	Shropshire. 8. Onny River.	9. Norbury.	10. Chirbury.	11. Church Stretton.	12. Bog Mine.	Counties. South Wales.* a. Pembrokeshire.	b. Caermarthenshire.	c. Cardiganshire.	d. Radnorshire.	England. e. Gloucestershire.	f. Worcestershire.	g. Shropshire.	Scotland.	Ireland.	Pass to Wenlock Beds.
		PROTOZOA.																						
		†*Fucoides gracilis*, Hall							×											×				?
		‡*Cliona prisca*, M'Coy																				×		
		Clathrodictyon vesiculorum, Nich.																						
		ACTINOZOA.																						
		Alveolites La Bechei, M'Edw.							×											×		?	×	×
		Cœnites intertextus, Eichw.																						
×	×	*Favosites aspera*, D'Orb.	×			×		×	×			×		×	×	×			×	×	×			×
×		*F. cristata*, Blum.							×											×				×
×	×	*F. Gothlandica*, Fougt.							×	×										×		×		×
×	×	*F. multipora*, Lonsd.												×		×				×				×
×	×	*Halysites catenulatus*, Linn.	×				×		×							×			×	×				×
×	×	*Heliolites favosus*, M'Coy (*Lyopora*)											×											
		H. inordinatus, Lonsd.			×		×												×					
	×	*H. interstinctus*, Wahl.	×		×		×		×							×			×	×	×			×
	×	*H. megastoma*, M'Coy							×											×				×
	×	*H. tubulatus*, Lonsd.	×												?	×				×	×			×
		La Becheia conferta, Lonsd.																		×	×		×	×
	×	*Omphyma turbinata*, Linn.				×	×		×					×	×				×	×	×			×
	×	*Palæocyclus porpita*, Linn.					×	×											×					×
	×	*P. præacutus*, Lonsd.					×		×										×	×				×
	×	*Petraia bina*, Lonsd.	×				×	×	×		×			×	×	×			×	×	×			×
		P. du Noyeri, Baily																						
	×	*P. elongata*, M'Coy	×		×		×	×	×		×				×	×		×	×	×	×			×
×	×	*P. rugosa*, Phill.																						
×	×	*P. subduplicata*, M'Coy (*Lindstromia*).	×	×	×	×	×	×	×	×	×	×	×	×	×	×			×	×	×	×	×	×
×	×	*P. uniserialis*, M'Coy	×													×								
	×	*P. ziczac*, M'Coy																					×	
×	×	*Plasmopora patelliformis*, Lonsd.	×													×							×	×
		Ptychophyllum patellatum, Schloth.							×											×			×	×
		Lindströmia lævis, *N. and E.*																				×		
		Syringopora bifurcata, Lonsd.	×		?				×							×					×	×	×	×
	×	*S. Lonsdaleiana*, M'Coy																						
		S. serpens, Linn.	×						×		×					×				×	×	×	×	×
		Streptelasma (*Petraia*) *æquisulcata*																				×		
		Propora Edwardsii, *N. and E.*																				×		
		Pinacopora Andersoni, *N. and E.*																				×		
		ECHINODERMATA.																						
×		*Actinocrinus pulcher*, Salt.																					×	×
		Cyclocystoides Davisii, Salt.			×	×									×				×					
		Palæaster coronella, Salt.				×									×					×				
		Periechocrinus moniliformis? Mill.						×											×					×
		Palæchinus Phillipsiæ, Forbes							×											×	×			
		ANNELIDA.																						
×	×	*Cornulites serpularius*, Schloth.				×	×	×	×	×			×	×	×					×	×	×	×	×
		Spirorbis Lewisii, Sow.							×						×							×		×
	×	*Tentaculites anglicus* Salt.		×	×	×		×	×		×	×	×	×	×				×	×	×	×	?	×
	×	*T. ornatus*, Sow.							†											×	×	?		×
		CRUSTACEA.§																						
	×	*Acidaspis Brightii*, M'Edw.	×	×					×							×	×		×		×			×
×	×	*Calymene brevicapitata*, Portl.													×					×		×	×	×

* Many species occur in Glamorganshire (Rhymney and Pen-y-lan) near Cardiff. *Vide* Sollas, Quart. Journ. Geol. Soc., Vol. 35, pp. 475–507. These are named and catalogued in Mr. Sollas's paper, and to which is added 12 new species from the Rhymney and Pen-y-lan area.

† Plant. ‡ Sponge.

§ Many species essentially Scotch are not noticed here, not having comparison with the Welsh forms.

| Caradoc. | Lower Llandovery. | Upper Llandovery or May Hill Sandstone Species. | Localities. | | | | | | | | | | | | | | | Counties. | | | | | | | | | | | | | | |

| Caradoc. | Lower Llandovery. | Upper Llandovery or May Hill Sandstone Species. | Localities. | | | | | | | | | | | | | | Counties. | | | | | | | | | | | | | |

| Caradoc. | Lower Llandovery. | Upper Llandovery or May Hill Sandstone Species. | Localities. | | | | | | | | | | | | | | Counties. | | | | | | | | | | | | | |

Caradoc.	Lower Llandovery.	Upper Llandovery or May Hill Sandstone Species.	Localities. South Wales. 1. Llandovery.	2. Builth.	3. Presteign.	4. Marloes Bay.	Gloucestershire. 5. May Hill and Huntley.	Worcest. 6. Tortworth.	7. Malvern Area.	Shropshire. 8. Onny River.	9. Norbury.	10. Chirbury.	11. Church Stretton.	12. Bog Mine.	Counties. South Wales. a. Pembrokeshire.	b. Caermarthenshire.	c. Cardiganshire.	d. Radnorshire.	England. e. Gloucestershire.	f. Worcestershire.	g. Shropshire.	Scotland.	Ireland.	Pass to Wenlock Beds.
		CEPHALOPODA—*cont.*																						
×		*O. filosum*, Sow. - - -											×								×			
×		*O. gregarium*, Sow. - - -																			×			
×	×	*O. ibex*, Sow. - - - -							×											×	×			
		O. subgregarium, M'Coy - -																				×		×
×		*O. tenuicinctum*, Portl. - -																						×
×	×	*O. tenuistriatum*, Münst. - -											×		×							×		
		Phragmoceras compressum, Sow.													×	×						×		
		P. ventricosum, Sow. - -					×		×										×	×	×			×
	×	*Tretoceras bisiphonatum*, Sow. -	×													×								

R. E.

Chief Localities for Upper Llandovery or May Hill Fossils.

PEMBROKESHIRE.

Marloes Bay -

Omphyma turbinata, M'Ewd.
Favosites (Stenopora) aspera, D'Orb.

ANNELIDA.

Tentaculites anglicus, Salt.
Cornulites serpularius, Schloth.

CRUSTACEA.

Phacops Downingæ, Murch.

BRACHIOPODA.

Rhynchonella nucula, Sow.
Spirifera elevata, Dalm.

LAMELLIBRANCHIATA.

Pterinea retroflexa, Wahl.
Modiolopsis antiqua, Sow.
Orthonota inornata, Phill.
Lyrodesma cuneata, Phill.

GASTEROPODA.

Euomphalus funatus, Sow.
Trochus multitorquata, M'Coy.
Raphistoma lenticularis, Sow.

Marloes Bay—*cont.*

HETEROPODA.

Bellerophon trilobatus, Sow.

CŒLENTERATA.

Wooltack -

Favosites fibrosa? Goldf.

ANNELIDA.

Tentaculites anglicus, Salt.
Cornulites serpularius, Schloth.

CRUSTACEA.

Encrinurus punctatus, Brünn.
Proetus Stokesii, Murch.
Phacops Stokesii, M'Edw.

BRACHIOPODA.

Lingula.
Strophomena alternata? Con.
Orthis elegantula, var. *Davidsoni*, De Vern.
O. protensa, Sow.
Chonetes striatella, Dalm.

R. E.

CAERMARTHENSHIRE.

Castell-craig-Gwyddon.

CŒLENTERATA.

Strephodes.
Petraia elongata, M'Coy.
P. uniserialis, M'Coy.
P. crenulata? M'Coy.
Halysites catenularius, Linn.
Favosites multipora, Lonsd.
F. aspera, D'Orb.

CRINOIDEA.

Encrinital stems, &c., &c.

Castell-craig-Gwyddon—*cont.*

CRUSTACEA.

Proetus latifrons, M'Coy.
Acidaspis Brightii, M'Edw.
Cheirurus bimucronatus, Murch.

BRACHIOPODA.

Leptæna scissa, Salt.

GASTEROPODA.

Cyclonema crebristria, M'Coy.

CAERMARTHENSHIRE—*continued.*

LLANDOVERY -	CŒLENTERATA. *Strephodes?* *Petraia uniserialis*, M'Coy. *P. subduplicata*, M'Coy. *Halysites catenularius*, Linn. *Favosites aspera*, D'Orb. CRUSTACEA. *Calymene Blumenbachii*, Brong. *Illænus Bowmanii*, Salt. *Encrinurus punctatus*, Brünn. *Proœtus Stokesii*, Murch. *Acidaspis Brightii*, M'Coy. BRYOZOA. *Retiolites.* *Fenestella assimilis*, Lonsd. *Ptilodictya explanata*, M'Coy. BRACHIOPODA. *Stricklandinia (Pentamerus) lens*, Sow. *Pentamerus oblongus*, Sow. *P. undatus*, Sow. *Rhynchonella nucula*, Sow. *Meristella crassa*, Sow. *Strophomena rhomboidalis*, Wilck. *S. pecten*, Linn. *S. antiqua*, Sow. *Orthis reversa*, Salt. *O. calligramma*, Dalm. *O. elegantula*, Dalm. *Leptæna transversalis*, Wahl. *L. quinquecostata*, M'Coy. *Spirifera exporecta*, Wahl.	LLANDOVERY—*cont.*

GLOUCESTERSHIRE—*continued.*

TORTWORTH—*cont.*	HYDROZOA. *Monograptus priodon*, Bronn. BRACHIOPODA. *Strophomena arenacea*, Salt. *S. compressa*, Sow. *Orthis reversa.* *Chonetes striatella?* Dalm.	TORTWORTH—*cont.*	*Atrypa hemisphærica*, Sow. *Spirifera elevata*, Dalm. LAMELLIBRANCHIATA. *Orthonota amydalina*, Sow. GASTEROPODA. *Euomphalus sculptus*, Sow.

R. E.

WORCESTERSHIRE.

MALVERN	CŒLENTERATA. *Palæocyclus præacutus*, Lonsd. *Petraia subduplicata*, M'Coy. *P. bina*, Phill. *Heliolites interstinctus*, Wahl. *H. megastoma*, M'Coy. *Favosites aspera*, D'Orb. *F. cristata*, Blum. ASTEROIDEA. *Palæaster coronella*, Salt. PALÆCHINIDÆ. *Palæchinus Phillipsiæ*, Forbes. ANNELIDA. *Tentaculites anglicus*, Salt. *Cornulites serpularius*, Schloth. CRUSTACEA. *Illænus Barriensis*, Murch. *Calymene Blumenbachii*, Brong. *Encrinurus punctatus*, var. *arenaceous?* Brunn. *Proætus latifrons*, M'Coy. *P. Stokesii*, Murch. BRYOZOA. *Fenestella scalpellum?* Lonsd. BRACHIOPODA. *Stricklandina* (*Pentamerus*) *lirata*, Sow. *Pentamerus oblongus*, Sow. *P. globosus*, Sow. *P. undatus*, Sow. *Rhynchonella decemplicata*, Sow.	MALVERN—*cont.*	*R. nucula*, Sow. *R. borealis*, Schloth. *Lingula crumena*, Phill. *L. parallela*, Phill. *Strophomena rhomboidalis*, Wilck. *Strophomena arenacea*, Salt. *S. simulans*, M'Coy. *S. applanata*, Salt. *S. compressa*, Sow. *Orthis reversa*, Salt. *O. calligramma*, Dalm. *O. elegantula*, Dalm. *Leptæna transversalis*, Wahl. *Atrypa hemisphærica*, Sow. *Spirifera exporecta*, Wahl. *S. elevata*, Dalm. LAMELLIBRANCHIATA. *Pterinea demissa*, Con. *Ctenodonta deltoidea*, Phill. *C. rastnori*, Sow. *C. lingualis*, Phill. *C. rhomboide*, Phill. *Area subæqualis.* GASTEROPODA. *Pleurotomaria fusicarina*, Phill. HETEROPODA. *Bellerophon bilobatus*, Sow. CŒLENTERATA. *Petraia subduplicata*, M'Coy. *P.* var. *cremulata*, M'Coy. *Palæchinus Phillipsiæ*, Forbes. *Rhynchonella nucula*, Sow.
		ABBERLEY HILLS.	
		WORCESTER BEACON, MALVERNS.	

R. E.

RADNORSHIRE.

PRESTEIGN	CŒLENTERATA. *Petraia elongata*, M'Coy. *P. subduplicata* M'Coy. *P.*, sp. ANNELIDA. *Tentaculites anglicus*, Salt. CRUSTACEA. *Calymene Blumenbachii*, Brong. *Illænus Thomsoni*, Salt. *Retiolites.* *Phacops Weaveri*, Salt. *P. imbricatulus*, Ang. BRACHIOPODA. *Pentamerus oblongus*, Sow. *Rhynchonella decemplicata*, Sow.	PRESTEIGN—*cont.*	*R. nucula*, Sow. *Strophomena arenacea*, Salt. *S. compressa*, Sow. *Orthis calligramma*, var. *Davidsoni*, De Vern. *O. elegantula*, Dalm. *Atrypa hemisphærica*, Sow. GASTEROPODA. *Clyclonema crebristria*, M'Coy. *Holopella cancellata*, Sow. *Macrocheilus fusiformis*, Sow. HETEROPODA. *Bellerophon dilatatus*, Sow. CEPHALOPODA. *Lituites cornu-aristes*, Sow.

R. E.

SHROPSHIRE.

CHURCH STRETTON.

CŒLENTERATA.
Petraia subduplicata, M'Coy.
Favosites aspera, D'Orb.

ANNELIDA.
Tentaculites anglicus, Salt.
Cornulites serpularius, Schloth.

CRUSTACEA.
Calymene Blumenbachii, Brong.
Encrinurus punctatus, var. *arenacea*, Brunn.

BRYOZOA.
Ptilodictya lanceolata, Goldf.

BRACHIOPODA.
Pentamerus oblongus, Sow.
P. undatus, Sow.
Rhynchonella decemplicata, Sow.
Strophomena arenacea, Salt.
S. pecten, Linn.
Orthis elegantula, Dalm.
Atrypa hemispherica, Sow.

LAMELLIBRANCHIATA.
Modiolopsis antiqua, Sow.

GASTEROPODA.
Acroculia haliotis, Sow.
Raphistoma lenticularis, Sow.
Turbo tritorquatus, M'Coy.

HETEROPODA.
Bellerophon dilatatus, Sow.
Ecculiomphalus lævis, Sow.

CEPHALOPODA.
Orthoceras filosum, Sow.

CHIRBURY
Cornulites serpularius, Schloth.
Favosites aspera, D'Orb.

CRUSTACEA.
Calymene Blumenbachii, Brong.
Illænus Bowmanii, Salt.
Encrinurus punctatus, Brünn.
Proetus Stokesii, Murch.
Phacops Stokesii, M'Edw.

BRACHIOPODA.
Stricklandinia lens, Sow.
Pentamerus oblongus, Sow.
Rhynchonella decemplicata, Sow.
R. borealis, Schloth.
Strophomena rhomboidalis, Wilck.

CHIRBURY—*cont.*
S. compressa, Sow.
Orthis reversa, Salt.
O. calligramma, Dalm.
O. elegantula, Dalm.
Leptæna transversalis, Wahl
Atrypa marginalis, Dalm.
A. hemispherica, Sow.
Spirifera exporrecta, Wahl.

LAMELLIBRANCHIATA.
Pterinea retroflexa, Wahl.

GASTEROPODA.
Acroculia haliotis, Sow.
Holopella cancellata, Sow.

NORBURY
CŒLENTERATA.
Petraia elongata, M'Coy.
P. bina, Phill.
P. subduplicata, M'Coy.

ANNELIDA.
Tentaculites anglicus, Salt.

CRUSTACEA.
Calymene Blumenbachii, Brong.
Proetus Stokesii, Murch.
Phacops Stokesii, M'Edw.
P. Downingiæ, Murch.
Cheirurus bimucronatus, Murch.

BRACHIOPODA.
Stricklandinia lens, Sow.
Pentamerus oblongus, Sow.
Rhynchonella decemplicata, Sow.
Strophomena rhomboidalis.
Orthis reversa, Salt.
O. elegantula, Dalm.
Leptæna transversalis, Wahl.
Atrypa hemisphærica, Sow.
Spirifera plicatella, Linn.

LAMELLIBRANCHIATA.
Pterinea retroflexa, Wahl.

GASTEROPODA.
Natica, sp.
Holopella cancellata, Sow.
Acroculia haliotis, Sow.
Raphistoma lenticularis, Sow.
Euomphalus rugosus?

HETEROPODA.
Bellerophon expansus, Sow.

WALSALL
Phacops caudatus, Brünn
P. Stokesii, M'Edw.
Rhynchonella sexcostata, M'Coy.

BRECONSHIRE.

Builth - -	Cœlenterata. *Aulacophyllum mitratum*, His. *Petraia subduplicata*, M'Coy. Crustacea. *Illænus Thomsoni*, Salt. Brachiopoda. *Stricklandinia lens*, Sow. *Strophomena rhomboidalis*, Wilck.	Builth—*cont.*	*S. pecten*, Linn. *S. applanata*, Salt. *Orthis calligramma*, var. *Davidsoni*, Salt. *Leptæna scissa*, Salt. *L. transversalis*, Wahl. *Atrypa hemisphærica*, Sow. *Spirifera exporrecta*, Wahl. *Pentamerus undatus*, Sow.

R. E.

Upper Llandovery or May Hill Fossils.

Name.	Localities in Wales and Shropshire, &c.
Cœlenterata (Zoophyta).	
Omphyma turbinata, M'Edw. - -	Marloes Bay; Pembrokeshire.
Strephodes - - - -	Castell-craig-Gwyddon; Llandovery.
Palæocyclus porpita, Linn. - -	Mav Hill; Tortworth.
P. præacutus, Lonsd. - -	Malvern Hills.
Aulacophyllum mitratum, His. - -	Builth.
Petraia elongata, Phill. - - -	Castell-craig-Gwyddon; Pen-y-lan; Presteign; May Hill; Tortworth; Norbury, &c.
P. uniserialis, M'Coy - -	Castell-craig-Gwyddon, S.E. of Llandovery.
P. subduplicata, M'Coy - - -	Pen-y-lan; Llandovery; Builth; Presteign; May Hill; Church Stretton; Malvern.
P., var. *crenulata* ? M'Coy - -	Castell-craig-Gwyddon; Abberley Hills; May Hill; Norbury.
P. bina, Lonsd. - - - -	May Hill; Tortworth; Norbury; Malvern.
Halysites catenularius, Linn. - -	Castell-craig-Gwyddon and Pen-y-lan; Llandovery; May Hill.
Heliolites interstinctus, Wahl. - -	May Hill; Malvern.
H. megastoma, M'Coy - - -	Malvern.
Favosites multipora, Lonsd. - -	Castell-craig-Gwyddon.
F. aspera, D'Orb. - - -	Castell-craig-Gwyddon; Pen-y-lan; Chirbury; Tortworth; Malvern; Church Stretton.
F. cristata, Blum. - - -	Malvern.
F. (*Stenopora*) *fibrosa*, Goldf. - -	Llandovery; Wooltack; Marloes Bay; May Hill; Tortworth.
Echinodermata.	
Palæaster coronella, Salt. - -	Malvern.
Palæchinus Phillipsiæ, Forbes - -	Worcester Beacon; Malvern.
Glyptocrinus, sp. - - -	Llangadoc.
Periechocrinus, sp. - - -	Tortworth.
Numerous portions of stems and arms of unknown forms occur in many localities.	Pen-y-lan; Builth; Llangadoc; Castell-craig-Gwyddon.
Annelida.	
Tentaculites anglicus, Salt. - -	Presteign; Wooltack and Marloes Bay; Malverns; Tortworth; Norbury; Church Stretton.
Cornulites serpularius, Schloth. - -	Marloes Bay; Wooltack; Malvern; Chirbury; Church Stretton.

Name.	Localities in Wales and Shropshire, &c.
Crustacea.	
Calymene Blumenbachii, Auct. - -	Pen-y-lan; Llandovery; Presteign; Norbury; Chirbury; Church Stretton; Malvern.
Illænus Barriensis, Salt. - -	Malvern?
I. Thomsoni, Salt. - - -	Builth; Onny River; Presteign; Pen-y-lan.
I. Bowmanni, Salt. - - -	Llandovery; Chirbury.
Encrinurus punctatus, var. *arenaceus*, Brünn.	Llandegle; Pen-y-lan; S. of Llandovery; Wooltack; Chirbury; Church Stretton; Walsall; Malvern; Tortworth; May Hill, &c.
Proetus latifrons, M'Coy - -	Castell-craig-Gwyddon; Malvern.
P. Stokesii, Murch. - - -	Norbury; Malvern; Chirbury; Llandovery; Wooltack.
Phacops Weaveri, Salt. - - -	Presteign; Tortworth.
P. Downingiæ, Murch. - - -	Marloes Bay; Norbury; Bogmine.
P. imbricatulus, Angelin - -	Presteign.
P. caudatus, Brün. - - -	Walsall.
P. Stokesii, Milne, Edw. - -	Llandovery; Wooltack; Tortworth; Chirbury; Norbury; Malvern; Walsall; Bogmine.
Acidaspis Brightii, Milne, Edw. -	Castell-craig-Gwyddon; Llandovery.
Cheirurus bimucronatus, Murch. -	Castell-craig-Gwyddon; Norbury.
Hydrozoa Bryozoa.	
Monograptus priodon, Bronn. - -	May Hill; Tortworth.
Reteolites venosus, Hall - - -	Pen-y-lan; Llandovery.
Fenestella subantiqua, D'Orb. - -	May Hill.
F. assimilis, Lonsd. - - -	S.E. of Llandovery.
F. scalpellum, Lonsd. - - -	Malvern.
Ptylodictya lanceolata, Lonsd. - -	Church Stretton.
P. explanata, M'Coy - - -	Ankerdine Hill; Llandovery.
Brachiopoda.	
Stricklandinia (*Pentamerus*) *lens*, Sow. -	Builth; Llandovery; May Hill; Norbury; Chirbury.
S. lirata, Sow. - - - - -	Malvern; May Hill; N.E. of Chirbury.
Pentamerus oblongus, Sow. (including *P. lævis*, Sow.)	Builth; Pen-y-lan; Llandovery; Presteign; Malvern; Norbury; Church Stretton; Chirbury.
P. globosus, Sow. - - -	Llandeilo; Malvern.
P. undatus, Sow. - - -	Builth; Llandovery; Malvern; Church Stretton.
Rhynchonella decemplicata, Sow. -	Presteign; Malvern; Minton; Chirbury; Norbury; Church Stretton.
R. nucula, Sow. - - - -	Marloes Bay; Llandovery; Malvern; Presteign; May Hill; Worcester Beacon; Bogmine.
R. sexcostata, M'Coy - - -	Huntley Hill; Walsall; Malvern.
R. borealis, Schloth. - - -	Chirbury; Malvern.
R. navicula, Sow. - - -	May Hill.
Atrypa Grayii, Dav. - - -	Glansevin, near Llandovery.
Meristella didyma, Dalm. - -	Glansevin; Llandovery.
M. crassa - - - -	Llandovery.
M. tumida, Dalm. - - -	May Hill.
Lingula, sp. - - - -	Wooltack Park, Pembrokeshire.
L. crumena, Phill. - - -	Malverns.
L. parallela, Phill. - - -	Do.
L. Symondsii, Salter - - -	Pen-y-lan.

Name.	Localities in Wales and Shropshire, &c.
Strophomena rhomboidalis, Wilck. -	Builth; Pen-y-lan; Llandovery; Chirbury; Norbury; Malvern; May Hill.
S. alternata, Con. - - -	Wooltack, Pembrokeshire.
S. arenacea, Salt. - - -	Presteign; May Hill; Malvern; Tortworth; Church Stretton, &c.
S. simulans, M'Coy - -	Malverns.
S. pecten, Linn. - - - -	S. of Llandovery; Builth; Church Stretton; Bogmine; May Hill.
S. applanata, Salt. - - -	Builth; Malvern.
S. antiquata, Sow. - - -	Llandovery; Bogmine.
S. compressa, Sow. - - -	Presteign; Marloes Bay; Norbury; Chirbury; Tortworth; Malvern.
S. euglypha, Dalm. - - -	Pen-y-lan, Llandovery.
Orthis reversa, Salt. - - -	Llandovery; Malvern; Tortworth; Chirbury; Norbury; Bogmine.
O. calligramma, Dalm. (chiefly var. *Davidsoni*).	Presteign; Llandovery; Builth; Longwynd; Chirbury; May Hill; Malverns.
O. elegantula, Dalm. - - -	Llandovery; Presteign; Wooltack; Chirbury; Bogmine; Norbury; Malverns; May Hill; Church Stretton.
O. biforata, Schloth. - - -	Presteign; Bogmine.
O. biloba, Linn. - - - -	Mwmfre.
O. protensa, Sow. - - -	Wooltack Park.
Leptæna transversalis, Dalm. - -	Builth; N. of Llandovery; Pen-y-lan; Llangadock; Malvern; Longmynd; Norbury; Chirbury.
L. scissa, Salt. - - -	Builth; Cefn-craig-Gwyddon.
L. quinquecostata, M'Coy - -	Llandovery.
Chonetes minima - - -	Llangadock.
C. lævigata, Sow. - - -	Devil's Bridge.
C. striatella, Dalm. - - -	Wooltack; Tortwor t h
Atrypa marginalis, Dalm. - -	Llandovery; Chirbury.
A. reticularis, Linn. - - -	Mandwain; Llandovery.
A. hemisphærica, Sow. - - -	Llandeilo; Builth; Llangadock; Presteign; Castell-craig-Gwyddon; Malvern; May Hill; Tortworth; Church Stretton; Norbury; Chirbury.
Spirifera exporrecta, Wahl. - -	Tortworth; Chirbury; Malvern; S.E. of Llandovery; Builth.
S. elevata, Dalm. - - -	Marloes Bay; Tortworth; Malvern.
S. plicatella, Linn. - - -	Llangadock; May Hill; Norbury.
LAMELLIBRANCHIATA.	
Pterinea retroflexa, Wahl. - -	Marloes Bay; Norbury; Chirbury.
P. planulata, Conrad - - -	Glansevin; Llandovery.
P. demissa, Conrad - - -	Malvern.
Ctenodonta deltoidea, Phill. - -	Do.
C. Eastnori, Sow. - - -	Do.
C. lingualis, Phill. - - -	Do.
C. rhomboidea, Phill. - - -	Do.
Arca subæqualis, Sow. - - -	Do.
Mytilus mytilimeris, Conrad - -	May Hill.
Modiolopsis antiqua, Sow. - -	Marloes Bay; Church Stretton?
Lyrodesma cuneata, Phill. - -	Marloes Bay.
Orthonota inornata, Phill. - -	Do.
O. amygdalina, Sow. - - -	Tortworth.
Cardiola interrupta.	
C. striata.	

Name.	Localities in Wales and Shropshire, &c.
GASTEROPODA.	
Natica, sp.	Norbury; Bogmine.
Acroculia haliotis, Sow.	Chirbury; Norbury; Church Stretton.
Cyclonema crebristria, M'Coy	Presteign; Cefn-craig-Gwyddon.
Euomphalus funatus, Sow.	Marloes Bay; May Hill.
E. sculptus, Sow.	May Hill; Tortworth.
E. prænuntius, Phill.	May Hill.
Trochus multitorquatus, M'Coy	Marloes Bay.
Holopella cancellata, Sow.	Presteign; Chirbury; Norbury; Bogmine.
H. obsoleta, Sow.	Bogmine.
Pleurotomaria fissicarina, Phill.	Malvern.
Raphistoma lenticularis, Sow.	Marloes Bay; Norbury; Church Stretton.
Macrocheilus fusiformis, Sow.	Presteign.
Turbo tritorquatus, M'Coy	Pen-y-lan; Llandovery; Church Stretton.
HETEROPODA.	
Bellerophon bilobatus, Sow.	Malvern.
B. dilatatus, Sow.	Presteign; Gorllwynfach; Church Stretton.
B. expansus, Sow.	Norbury; Bogmine.
B. trilobatus, Sow.	Llangadock; Marloes Bay; Bogmine.
PTEROPODA.	
Ecculiomphalus lævis, Sow.	Church Stretton.
CEPHALOPODA.	
Orthoceras filosum, Sow.	Do.
O. tenuistriatum, Sow.	Haverfordwest.
Tretoceras bisphonatum, Sow.	Gorllwynfach.
Lituites cornu-arietis, Sow.	Presteign.

R. E.

LIST of FOSSILS from the UPPER LLANDOVERY ROCKS of the BOGMINE, near SHELVE.

At the Bogmine, near Shelve in Shropshire, there is a small outlying patch of fossiliferous grit. It lies unconformably on the Llandeilo flags, and physically may be considered an undoubted outlier of the Upper Llandovery rocks that skirt the base of the Cambrian rocks of the Longmynd and the adjacent Lower Silurian strata. The whole having been formed during a period of submergence, the outlier may be of slightly later date than the Upper Llandovery rocks at the base of the hill, even though they were originally continuous. In that case the patch at the Bogmine during the later stage of the submergence of the Old Silurian and Cambrian land, was still a marginal deposit, while the continuation of the same formation, formed at an earlier period of the submergence, was out at sea in deeper water.

The following list of fossils bears out this view:—

CŒLENTERATA.

Omphyma turbinata, M. Edw.
Petraia bina, Lonsd.
Favosites.

ANNELIDA.

Tentaculites anglicus, Salt.
Cornulites serpularius, Schloth.

CRUSTACEA.

Calymene brevicapitata, Port.
Illænus Barriensis, Murch.
Proetus Stokesii, Murch.
Phacops Downingiæ, Murch.
P. Stokesii, M. Edw.

POLYZOA.

Fenestella subantiqua.

BRACHIOPODA.

Rhynchonella nucula, Hall.
R. borealis, Schloth.
Strophomena pecten, Sow.
S. antiquata, Sow.
S. compressa, Sow.
Orthis reversa, Salt.
O. testudinaria, Dalm.
O. elegantula, Dalm.
O. biforata, Schloth.
O. radians, Sow.
Meristella crassa, Sow.
Chonetes lævigata, Sow.

LAMELLIBRANCHIATA.

Pterinea retroflexa, Wahl.
Goniophora cymbæformis, Sow.
Mytilus mytilimeris, Conrad.

GASTEROPODA.

Natica, sp.
Holopella cancellata, Sow.
H. obsoleta, Sow.
Raphistoma lenticularis, Sow.
Turbo tritorquatus, M'Coy.

HETEROPODA.

Bellerophon expansus, Sow.
B. trilobatus, Sow.
B. carinatus.

CEPHALOPODA.

Lituites cornu-arietis, Sow.
Orthoceras.

WENLOCK SERIES.

This great formation, long ago described in detail for North Wales by Prof. Sedgwick, covers up with a slight degree of unconformability the Lower Silurian series; and in the remarkable sandy character of its base it differs so widely from the typical Wenlock rocks of the Silurian region, that the fossil contents of the two regions may well be supposed to be different. Professor Sedgwick's paper shows that one of the commonest fossils along the range of Modwl Eithin in Denbighshire, and the western slopes of the Berwyns, is the *Chonetes striatella*, Dalm., the *Leptæna lata*, von Buch, of the Silurian system. This is a fossil rarely found in Wenlock stata; it is characteristic of the sandy mudstones of the Upper Ludlow rocks, and here in these lowest Wenlock beds it is associated with the *Bellerophon trilobatus*, a fossil not less characteristic of the Uppermost Silurian sandstones (or "tilestones" of the Silurian system). This commingling of the Ludlow and Wenlock types, however, does not destroy the very considerable difference between the fossils of the two series; it only modifies them.

The fossils of the sandy strata about Llansannan and Llangollen have been separated as a higher Wenlock group (p. 450); but there is in truth but little variety in the fauna of the Wenlock rocks of North Wales, except where the respective conditions of black shales and coarse arenaceous grit prevail. In the former we find abundance of *Graptolites* and thin-shelled *Orthoceratites*, with *Cardiola* and very few Brachiopoda. In the latter, the Brachiopoda and Gasteropoda are abundant, and corals are not rare; but a *Graptolite* or an *Orthoceratite* is seldom met with. *Encrinites* are plentiful in both kinds of rock, but few are Dudley species.

[The fauna of the Tarannon and Denbighshire grits is a small one comparatively, as would be expected from the nature or physical condition of the beds, and as a lower division of the Wenlock rocks or group, the fossils may

readily be kept separate, for few species are common to the Upper or true Wenlock series of the Silurian area. Only 54 species are known in the Tarannon beds, and 57 in the Denbighshire grits, and if we include the Woolhope beds in the lower division, which possesses a fauna of 138, the number is still small, when we remember that the whole Wenlock is 523. Again, the whole 54 species in the Tarannon shales pass up, not one being peculiar, and the Denbighshire grits beds only contain three species which do not occur in the Wenlock proper, viz., *Bellerophon expansus*, *Murchisonia articulata*, and *M. carinata*. The Woolhope beds are allied to the Wenlock shales and limestones through 124 species out of 138 known in the Woolhope, the remaining are Woolhope forms only.

The Tarannon and Denbigshire grits and Woolhope beds have 30 species in common out of 145 occurring in all 3 divisions. The Lower and Upper Wenlock, as now defined, are therefore Palæontologically a separate series.

The large fauna, known in the upper division or Wenlock shales and limestones (473 species), is doubtless due to the nature of the sediments during life and deposition, and both the limestones and shales afford a good matrix for their preservation. The occurrences in the upper Wenlock, or Wenlock proper, number 473, whereas in the three divisions of the Lower Wenlock they are only 219. The upper possessing 3 to 1 of the lower where the life of the period culminated, but 124 survived, passed to, or are common to the Ludlow, thus leaving 204 species as peculiarly Ludlow.] R. E.

GROUPING and DISTRIBUTION of the WENLOCK FOSSILS, N. WALES.

Name.	Locality.
Favosites alveolaris, Blainv. - -	Llangynyw Rectory, Montgomeryshire; Craig-hir; Mwdwl Eithin; E. of Merchlin.
F. fibrosa, Goldf. - - -	Moel Seisiog; Mwdwl Eithin; E. of Merchlin, S. of Conway.
— var. *ramulosa*, Phill. - - -	E. of Merchlin.
Petraia subduplicata, M'Coy - -	Plas Madoc.
P. bina, Lonsd. (small) - -	Moel Seisiog.
Syringopara, sp. with tubercles inside -	Do.
Encrinite stems - - - -	Craig-hir.
Glyptocrinus, sp. - - -	Mwdwl Eithin; Moel Seisiog; Plas Madoc.
Actinocrinus, stems only - -	E. of Merchlin.
A. pulcher, Salter - - -	Oernant; Nant-glyn; Maes-tyddyn; Nant-gwrhwyd-uchaf.
Trails of *Annelides* - - -	Oernant.
Cornulites serpularius, Schl. - -	Plas Madoc.
Tentaculites, sp. - - -	Do.
CRUSTACEA.	
Calymene Blumenbachii, Brong. -	Craig-hir; Mwdwl Eithin; Moel Seisiog E. of Merchlin; Plas Madoc.
Homalonotus, sp. - - -	Mwdwl Eithin.
Phacops Downingiæ, Murch., var. -	Mwdwl Eithin; Moel Seisiog; Plas Madoc; E. of Merchlin.
P. caudatus, Brong. - - -	Moel Seisiog; Plas Madoc.
P. Stokesii, Milne-Edw. - - -	Llangynyw Rectory (M'Coy).
Encrinurus punctatus, Brünn - -	Mwdwl Eithin; Plas Madoc.
Beyrichia Klödeni, M'Coy - -	E. of Merchlin.
Monograptus priodon, Bronn. (*M. ludensis*).	Llanrwst; Llangynyw Rectory; Oernant; Nant Morfydd; Craig-ddu-allt; Nant Glyn; Maes Tyddyn; Gwyddelwern; Cefn-Grugos, W. of Llanfyllin.
M. sagittarius, Linn. ? - - -	Moel Seisiog (M'Coy).

Name.	Locality.
BRACHIOPODA.	
Atrypa reticularis, Linn. - -	Craig-hir; Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.
A., sp. - - - - -	E. of Merchlin.
Chonetes lævigata, Sow. - -	Gwyddelwern.
C. minima, Sow. - - -	Do.
Leptæna transversalis, Dalm. - -	Craig-hir; Mwdwl Eithin; Moel Seisiog; Plas Madoc.
Orthis elegantula, Dalm. - -	Craig-hir; Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.
O. elegantula (var., with flatter ventral valve).	E. of Merchin.
O., with simple plaits - - -	Do.
Rhynchonella borealis, Schl. - -	Do.
R. nucula, Sow. - - - -	Mwdwl Eithin; Moel Seisiog; E. of Merchlin; Plas Madoc.
R. decemplicata, Sow. - - -	Mwdwl Eithin; Plas Madoc.
R. do. ? - - -	Plas Madoc.
R.,—two species - - -	Mwdwl Eithin; Plas Madoc.
R.,—very fine ribs - - -	Moel Seisiog.
Strophomena compressa, Sow. - -	Do. (M'Coy).
Spirifera trapezoidalis, Dalm. - -	Craig-hir; Plas Madoc.
S. elevata, Dalm. - - -	Mwdwl Eithin; Plas Madoc; E. of Merchlin.
S. plicatella, Linn. - - -	E. of Merchlin.
S. percrassa, M'Coy - - -	Moel Seisiog (M'Coy).
Retzia cuneata, Dalm. - - -	Plas Madoc.
LAMELLIBRANCHIATA.	
Ctenodonta,—flat sp. - - -	Plas Madoc; Mwdwl Seisiog; Gwyddelwern.
C. levata, M'Coy, not of Hall - -	Plas Madoc.
C. (*Arca*) *Edmondiiformis*, M'Coy -	Moel Seisiog; Llangynyw Rectory.
Cardiola interrupta, Sow. - -	Oernant; Maes Tyddyn; Llangynyw.
C., sp. - - - - -	Maes Tyddyn.
Pterinea retroflexa? or *P. rectangularis*	Mwdwl Eithin.
Mytilus, small convex sp. - -	Maes Tyddyn.
M. Chemungensis? Conrad. - -	Plas Madoc.
M. unguiculatus, Salt. - - -	Do.
Modiolopsis, sp. - - - -	Do.
Clidophorus ovalis, M'Coy - -	Do.
GASTEROPODA.	
Euomphalus, like *E. carinatus*, Sow. -	Oernant.
E. (or *Platyschisma*) shell, thin -	Craig-hir.
Loxonema elegans, M'Coy - -	Do. (also at Vinnal Hill, Ludlow).
Murchisonia Lloydii, Sow. - -	Do.
M.,—sp. (flat sides) - - -	Plas Madoc.
M.,—sp. (prominent whorls) - -	Do.
Holopella gregaria, Sow. - -	Do.
Acroculia haliotis, Sow. - -	Moel Seisiog; Plas Madoc.
Bellerophon carinatus, Sow. - -	Plas Madoc.
B. trilobatus, Sow. - - -	Do.
B. expansus, Sow. ? - - -	Do.
B. subdecussatus, M'Coy - -	Llanrwst.
CEPHALOPODA.	
Orthoceras annulatum, Sow. - -	Craig-hir.
O. primævum, Forbes - - -	Nant-glyn; Craig-hir.
O. angulatum, Wahl. - - -	Llangynyw Rectory (M'Coy).
O. subundulatum, Portl. - -	Craig-hir; Maes Tyddyn; Moel Seisiog; Llangynyw Rectory; Craig-ddu-allt.
O., sp. - - - - -	Plas Madoc.
Phragmoceras nautileum, Sow. - -	Do.
Lituites articulatus, Sow. ? - -	Nant-glyn.

Chief Localities for Wenlock Fossils in North Wales.

MONTGOMERYSHIRE.

Llangynyw Rectory.	*Favosites aspera*, D'Orb. *Phacops Stokesii*, M'Edw. *Monograptus priodon*, Bronn. *Arca Edmondiiformis*, M'Coy. *Cardiola interrupta*, Sow. *Orthoceras angulatum*, Wahl. *O. subundulatum*, Portl.
Craig-hir	*Favosites aspera*, D'Orb. *Encrinital* stems. *Calymene Blumenbachii*, Brong. *Atrypa reticularis*, Linn. *Leptæna transversalis*, Wahl. *Orthis elegantula*, Dalm. *Spirifera exporrecta*, Wahl. *Euomphalus*, sp.
Craig-hir—*cont.*	*Orthoceras annulatum*, Sow. *O. subundulatum*, Portl. *O. primævum*, Forbes.
Mwdwl Eithin	*Favosites aspera*, D'Orb. *F. fibrosa*, Goldf. *Glyptocrinus*, 4 sp. *Calymene Blumenbachii*, Brong. *Homalonotus*, sp. *Phacops Downingiæ*, Murch. *Encrinurus punctatus*, Brünn. *Atrypa reticularis*, Linn. *Leptæna transversalis*, Wahl. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *R. decemplicata*, Sow. *Spirifera elevata*, Dalm. *Pterinia retroflexa*, Wahl.

R. E.

CARNARVONSHIRE.

E. of Merchlyn	*Favosites aspera*, D'Orb. *F. fibrosa*, Goldf. *F. fibrosa*, var. *ramulosa*, Phill. *Actinocrinus* stems. *Calymene Blumenbachii*, Brong. *Phacops Downingiæ*, Murch. *Beyrichia Klædeni*, M'Coy. *Atrypa reticularis*, Linn. *Atrypa*, sp. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *R. borealis*, Schloth. *Spirifera elevata*, Dalm. *S. plicatella*, Linn.
Moel Seisiog	*Favosites fibrosa*, Goldf. *Petraia bina*, Lonsd. *Glyptocrinus.* *Syringopora* (tubercules inside). *Calymene Blumenbachii*, Brong. *Phacops Downingiæ*, Murch. *P. caudatus*, Brong. *Monograptus sagittarius* Linn. *Atrypa reticularis*, Linn. *Leptæna transversalis*, Wahl. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *R.*, sp. *Strophomena compressa*, Sow. *Ctenodonta.* *C.* (*Arca*) *Edmondiiformis*, M'Coy. *Acroculia haliotis*, Sow. *Orthoceras subundulatum*, Portl.
Plas-Madoc	*Petraia subduplicata*, M'Coy. *Glyptocrinus*, 4 sp. *Cornulites serpularius*, Schloth. *Calymene Blumenbachii*, Brong.
Plas-Madoc—*cont.*	*Phacops Downingiæ*, Murch. *P. caudatus*, Brong. *Encrinurus punctatus*, Brünn. *Tentaculites*, sp. *Atrypa reticularis*, Linn. *Leptæna*, sp. *L. transversalis*, Wahl. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *R. decemplicata*, Sow. *R.*, 2 sp. *Spirifera exporrecta*, Wahl. *S. elevata*, Dalm. *Retzia cuneata*, Dalm. *Ctenodonta* sp. *C. levata*, M'Coy. *Mytilus Chemungensis?* Conrad. *M. unguiculatus*, Salter. *Modiolopsis.* *Clidophorus ovalis?* M'Coy. *Murchisonia*, sp. *M.*, sp. *Holopella gregaria*, Sow. *Acroculia Haliotis*, Sow. *Bellerophon carinatus*, Sow. *B. trilobatus*, Sow. *B. expansus*, Sow. *Orthoceras.* *Phragmoceras nautileum*, Sow.
Oernant	*Actinocrinus pulcher*, Salter. *Annelidæ* (*trails of*). *Monograptus priodon*, Bronn. *Cardiola interrupta*, Sow. *Euomphalus like E. carinatus.*
Nant-Glyn	*Actinocrinus pulcher*, Salt. *Monograptus priodon*, Bronn. *Orthoceras primævum*, Forbes, *Lituites articulatus*, Sow.

CARNARVONSHIRE—*continued.*

MAESTYDDYN -	*Actinocrinus pulcher*, Salt. *Monograptus priodon*, Bronn. *Mytilus convex*, sp. *Orthoceras subundulatum*, Portl.	LLANRWST - -	*Monograptus priodon*, Bronn. *Bellerophon subdecussatus?* M'Coy.
		NANT MORYDD -	*Monograptus priodon*, Bronn.
		CRAIG-DDU-ALLT	*Monograptus priodon*, Bronn. *Orthoceras subundulatum*, Portl.
NANT - GWRH - WYD-UCHAF.	*Actinocrinus pulcher*, Salt.		R.H.

UPPER WENLOCK SPECIES, near Llansannan.

Beds above Denbighshire Grits.

Name.	Locality.
Favosites fibrosa, Goldf., var. *incrustans*	Frid-y-fedwen; Mynydd-Tryfan; Fron Fawr.
F., var. *ramulosa*, Phill. - -	Frid-y-fedwen; Mynydd-Tryfan; Cefn Barog; Fron-fawr.
Heliolites interstinctus, Wahl. - -	Fron-fawr.
Petraia bina, Lonsd. - - -	Frid-y-fedwen.
P., sp. - - - - -	Do.
Spongarium Edwardsii, Murch. -	Dinas Bran; Llangollen.
Encrinite stems - - - -	Frid-y-fedwen; Mynydd Tryfan; Cefn Barog; Fron-fawr; Bryn-mawr.
Serpulites dispar, Salt. - -	Dinas Bran (M'Coy).
Cornulites serpularius, Schl. - -	Fron-fawr.
Tentaculites ornatus, Sow. - -	Frid-y-fedwen; Mynydd Tryfan; Bryn-mawr.
Phacops caudatus, Brong. - -	Frid-y-fedwen; Cefn Barog.
Beyrichia Klædeni, M'Coy - -	Bryn-mawr; Capel-y-rhiw; Frid-y-fedwen; Cefn Barog; Fron-fawr.
Nodular var. of do. - - -	Capel-y-rhiw.
Cytheropsis, sp. - - -	Mynydd Tryfan.
Escharina or *Berenicea* - -	Frid-y-fedwen.
Graptolithus priodon, Bronn - -	Tyn-y-pwll; R. Dee, S. of Llangollen (M'Coy).
Protaster Sedgwickii, Forbes - -	Dinas Bran.
BRACHIOPODA.	
Atrypa reticularis, Linn. - -	Frid-y-fedwen; Mynydd Tryfan; Fron fawr; Cefn Barog; Bryn-mawr; Moel Fodig; (Mynydd-y-Gaer; Llanefydd, M'Coy).
A., sp. - - - - -	Frid-y-fedwen.
Chonetes striatella, Dalm. - -	Bryn-mawr; Frydd-y-fedwen; Mynydd Tryfan; Moel Fodig; Cefn Barog; Fron-fawr.
Orthis elegantula, Dalm. - -	Bryn-mawr; Capel-y-rhiw; Moel Fodig; Frid-y-fedwen; Mynydd Tryfan; Cefn Barog; Fron-fawr; R. Dee, S. of Llangollen; Mynydd-y-gaer.
O. lunata, Sow. - - - -	Dinas Bran (M'Coy).
Rhynchonella didyma, Dalm. - -	Frid-y-fedwen.
R. Wilsoni, Sow. - - -	Bryn-mawr; Mynydd Tryfan; Capel-y-rhiw.
R. nucula, Sow. - - - -	Mynydd-y-gaer; Bryn-mawr; Fron-fawr; Moel Fodig; Capel-y-rhiw; Llangollen.
R. navicula Sow - - -	Cefn Barog; Moel Fodig; Dinas Bran; Welshpool; Mynydd-y-gaer; Llanefydd.

Name.	Locality.
R., plaited sp.	Frid-y-fedwen.
Spirifera elevata, Dalm.	Bryn-mawr; Fridd-y-fedwen; Mynydd Tryfan; Fron-fawr; Moel Fodig.
S. crispa, Linn.	Llangollen.
Leptæna lævigata, Sow.	Mynydd-y-gaer; Llanefydd, near Ruthin; Welshpool.
L. minima, Sow.	Bryn-mawr; Mynydd Tryfan; Capel-y-rhiw; River Dee.
Strophomena euglypha, Dalm.	Frid-y-fedwen.
S. depressa, Dalm.	Bryn-mawr; Fridd-y-fedwen; Mynydd Tryfan; Cefn Barog; Fron-fawr.
S. funiculata, M'Coy	Moel Fodig.
S. filosa, Sow.	Bryn-mawr; Capel-y-rhiw; Mynydd Tryfan.
Lamellibranchiata.	
Ambonychia? acuticostata, M'Coy	Dinas Bran.
Goniophora cymbæformis, Sow.	Fridd-y-fedwen.
Pterinea retroflexa, Wahl.	Fron-fawr; Capel-y-rhiw?
Avicula mira, Barr?	Moel Fodig.
Cardiola interrupta, Sow.	Capel-y-rhiw; Mynydd Tryfan; Bryn-mawr; Yr Allt; Welshpool; Mynydd-y-gaer; Llanefydd.
Cardiola striata? Sow.	Mynydd Tryfan.
C., n. sp.	Tyn-y-pwll; Mynydd Tryfan.
Cucullella coarctata, Phill.	Dinas Bran (M'Coy).
C. antiqua, Sow.	Mynydd Tryfan.
Ctenodonta anglica, D'Orb.	Fron-fawr.
C. levata, M'Coy, not Hall	Dinas Bran (M'Coy).
Gasteropoda.	
Cyclonema, with three keels	Frid-y-fedwen.
Murchisonia Lloydii, Sow.	Mynydd Tryfan.
M., 2 sp.	Fridd-y-fedwen.
Holopella gracilior, M'Coy	Dinas Bran (M'Coy).
Loxonema sinuosa, Sow.	Fridd-y-fedwen.
Euomphalus funatus, Sow.?	Do.
Nucleobranchiata, &c.	
Bellerophon trilobatus, Sow.	Do.
B. carinatus, Sow.?	Do.
Theca Forbesii, Sharpe	Dinas Bran (M'Coy).
Cephalopoda.	
Orthoceras Sedgwicki, Forbes	Fridd-y-fedwen.
O. perelegans, Salt.	Do.
O. primævum, Forbes	Capel-y-rhiw; Tyn-y-pwll.
O. subundulatum, Portl.	Do.
O. bullatum, Sow.	Llyn Alwen (M'Coy).
O. ventricosum, Sharpe	Bron Einion; Pen-y-big (M'Coy).
O. laqueatum, Hall	Dinas Bran (M'Coy).
O. tenuicinctum, Portl.	Do.
O. tracheale, Sow.	Do.
Lituites articulatus, Sow.	Welshpool (M'Coy).

Chief Localities for Upper Wenlock Fossils near Llansannan.

DENBIGHSHIRE.

Fridd-y-fedwen.	*Favosites* (*Stenopora*) *fibrosa*, Goldf. *F.* (*Stenopora*), var. *incrustans*, M'Coy. *F.* (*Stenopora*), var. *ramulosa?* Phill. *Petraia bina*, Lonsd. *P.*, sp. *Encrinital* stems. *Tentaculites ornatus*, Sow. *Phacops caudatus*, Brong. *Beyrichia Klædeni*, M'Coy. *Escharina* or *Berenicea.* *Atrypa reticularis*, Linn. *A.*, sp. *Chonetes striatella*, Dalm. *Orthis elegantula*, Dalm. *Meristella* (*Rhynchonella*) *didyma*, Dalm. *Spirifera elevata*, Dalm. *Strophomena euglypha*, Sow. *S. rhomboidalis*, Wilck. *Goniopora cymbæformis*, Sow. *Cyclonema*, sp. *Loxonema sinuosa*, Sow. *Orthoceras.* *Murchisonia.* *Euomphalus funatus*, Sow. *Bellerophon trilobatus*, Sow. *B. carinatus*, Sow.
Mynydd Tryfan.	*Favosites* (*Stenopora*) *fibrosa*, Goldf. *F.* (*Stenopora*), var. *incrustans*, M'Coy. *F.* (*Stenopora*), var. *ramulosa*, Phill. *Encrinital* stems. *Tentaculites ornatus*, Sow, *Cytheropsis.* *Atrypa reticularis*, Linn. *Chonetes striatella*, Dalm. *Orthis elegantula*, Dalm. *Rhynchonella Wilsoni*, Sow. *Spirifera elevata*, Dalm. *Chonetes minima*, Sow. *Strophomena rhomboidalis*, Wilck. *S. filosa*, Sow. *Cardiola interrupta*, Sow. *C. striata*, Sow. *C.*, sp. *Cucullella antiqua*, Sow. *Murchisonia Lloydii*, Sow. *Holopella*, sp.
Fron-fawr	*Favosites* (*Stenopora*) *fibrosa*, Goldf. *F.* (*Stenopora*), var. *incrustans*, M'Coy. *F.* (*Stenopora*), var. *ramulosa*, Phill. *Heliolites interstinctus*, Wahl. *Encrinital* stems. *Cornulites serpularius*, Schloth. *Beyrichia Klædeni*, M'Coy. *Atrypa reticularis*, Linn. *Chonetes striatella*, Dalm. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *Spirifera elevata*, Dalm. *Strophomena rhomboidalis*, Wilck. *Pterinea retroflexa*, Wahl. *Cucullella*, sp. *Ctenodonta anglica*, D'Orb.
Cefn-Barog	*Favosites* (*Stenopora*) *fibrosa*, Goldf. *F.* (*Stenopora*), var. *ramulosa*, Phill. *Encrinital* stems. *Beyrichia Klædeni*, M'Coy. *Atrypa reticularis*, Linn. *Chonetes striatella*, Dalm. *Orthis elegantula*, Dalm. *Rhynchonella navicula*, Sow. *Strophomena rhomboidalis*, Wilck. *Phacops caudatus*, Brong.
Castell Dinas Bran.	*Spongarium Edwardsii*, Murch. *Favosites fibrosa*, Goldf. *Actinocrinus pulcher.* *Serpulites dispar*, Salt. *Rhynchonella navicula*, Sow. *R. nucula*, Sow. *Ambonychia acuticostata*, M'Coy. *Cucullella coarctata*, Phill. *Ctenodonta levata?* M'Coy. *Holopella gracilior*, M'Coy. *Theca Forbesii?* Sharpe. *Orthoceras laqueatum?* Hall. *O. tenuicinctum*, Portl. *O. tracheale*, Sow. *Cycloceras ibex*, Sow.
Llangollen	*Spongarium Edwardsii*, Murch. *Monograptus priodon*, Bronn. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *Spirifera crispa*, Linn.
Bryn Mawr	*Encrinital* stems. *Tentaculites ornatus*, Sow. *Beyrichia Klædeni*, M'Coy. *Atrypa reticularis*, Linn. *Rhynchonella Wilsoni*, Sow. *Chonetes striatella*, Dalm. *Chonetes minima*, Sow. *Orthis elegantula*, Dalm. *Chonetes minima*, Sow. *Strophomena rhomboidalis*, Wilck. *S. filosa*, Sow. *Caridola interrupta*, Sow. *Cyclonema* with 3 keels.
Capel-y-rhiw	*Beyrichia Klædeni*, M'Coy. *B. nodula*, var. *Rhynchonella Wilsoni*, Sow. *R. nucula*, Sow. *Chonetes minima*, Sow. *Strophomena filosa*, Sow. *Orthis elegantula*, Dalm. *Pterinea retroflexa*, Wahl. *Cardiola interrupta*, Sow. *Orthoceras primævum*, Forbes. *O. subundulatum*, Portl.
Tyn-y-pwll	*Monograptus priodon*, Bronn. *Cardiola.* *Orthoceras primævum*, Forbes, *O. subundulatum*, Portl.

DENBIGHSHIRE—*continued.*

MOEL FODIG -	*Atrypa reticularis*, Linn. *Chonetes striatella*, Dalm. *Orthis elegantula*, Dalm. *Rhynchonella nucula*, Sow. *R. navicula*, Sow. *Spirifera elevata*, Dalm. *Strophomena funiculata*, M'Coy. *Avicula mira*, Barr.	MYNYDD-Y-GAER —*cont.*	*Rhynchonella navicula*, Sow. *Cardiola interrupta*, Sow.
MYNYDD-Y-GAER	*Atrypa reticularis*, Linn. *Orthis elegantula*, Dalm.	LLANEFYDD -	*Atrypa reticularis*, Linn. *Rhynchonella navicula*, Sow. *Cardiola interrupta*, Sow. *Chonetes lævigata*, Sow.
		YR ALLT - -	*Orthis lunata?* Sow. *Cardiola interrupta*, Sow. R.E.

MONTGOMERYSHIRE.

WELSHPOOL -	*Strophomena lævigata*, Sow. *Cardiola interrupta*, Sow. *Lituites articulatus*, Sow. *Rhynchonella navicula*, Sow.	LLYN ALWEN -	*Orthoceras bullatum*, Sow.
		BRON EINION -	*Orthoceras ventricosum*, Sharpe.
		PEN-Y-BIG - -	*Orthoceras ventricosum*, Sharpe. R.E.

DISTRIBUTION of the WENLOCK SPECIES and their RELATION to the OLDER FORMATIONS and the LUDLOW above.

—	Wenlock Species.	Upper Silurian.														
		Wenlock.									Pass to Ludlow.		
		Lower.			Upper.	Districts.							
	Wenlock Species, showing Range and value of the Group.*	Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Wenlock Series.†	North Wales.	South Wales.	Scotland.	Ireland.	Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
	Llandeilo.															
	Caradoc.															
	Lower Llandovery.															
	Upper Llandovery.															
PROTOZOA -	*Cliona prisca* - -															
	Spongarium Edwardsii, Murch.							×								
	Cnemidium tenue, Lonsd.															
	Ischadites Grindrodi, Salt.															
	I. Königii, Murch. -	×														
	Stromatopora striatella, D'Orb.			×												
HYDROZOA‡ -	*Cyrtograptus Murchisoni*, Carr.															
	C. Linnarssoni, Lapw. -															
	Monograptus Flemingii -			×												
	M. Halli, Barr. - -															
	M. Bohemicus, Barr. -															
	M. vomarinus, Nich. -															
	M. priodon, Bronn. -	×	×		×											
	M. - - - -															
	M. - - - -															
	Retiolites geinitzianus -															
	Rastrites peregrinus, Barr.				×											
	Ptilograptus anglicus, Nich.															

* Most of the species in this list occur in the Malvern, Woolhope, Domington, Wenlock, and Dudley areas especially, or in the column headed Wenlock series—localities would have been too numerous to specialize. The Wenlock limestone of Dudley contains nearly all the known species.

† There is no column for England or the English species, as almost every species occurs in the classical localities of Wenlock, Dudley, Ludlow, &c., and the column headed Wenlock series embraces all not marked with an × to denote distribution.

NOTE.—1, Onny River.
2, Myddfai.
3, Llandovery.
4, Garfady.

‡ The Upper Wenlock species are about 18; the Tarannon forms number about 20 species, whether they are Upper Llandovery or Lower Wenlock it is difficult to [illegible] lock of Builth-yedd, 13 species; North Wales, 8; the Lake area, 16; the Riccarto[illegible] bed, about 10.

	Llandello.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species. / Wenlock Species, showing Range and value of the Group.	Upper Silurian. Wenlock. Lower. Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Upper. Wenlock Series.	Districts. North Wales.	South Wales.	Scotland.	Ireland.	Pass to Ludlow. Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
ACTINOZOA -					*Acervularia luxurians*, Eichw. (*A. ananas*).											
					Alveolites Grayi, M'Edw.											
				×	*A. La Bechei*, M'Edw. -							×	×			
		×			*A. repens*, Fougt. - -											
					A. seriatoporoides, M'Edw.											
					A. Fletcheri, Seeley -											
					A. seeleyi, Salt -											
				×	*Arachnophyllum typus*, M'Coy. (*Strombodes*).											
		×	×		*Aulacophyllum mitratum*, His.					×		×				
					Chonophyllum perfoliatum? M'Edw.											
				×	*Cænites intertextus*, Eichw.											
					C. juniperinus, Eichw. -											
					C. labrosus, M'Edw. -											
					C. linearis, M'Edw. -											
					C. strigatus, M'Coy -											
					Cyathaxonia siluriensis, M'Coy.											
			×		*Cyathophyllum angustum*, Lonsd.											
		×	×		*C. articulatum*, Wahl. -							×				
					C. flexuosum, Linn. -								×			
					C. Loveni, M'Edw. -								?			
		×			*C. pseudo-ceratites*, M'Coy					×	×					
					C. trochiforme, M'Coy -											
					C. truncatum, Linn. -								×			
					Cystiphyllum, M'Coy -											
			×		*C. cylindricum*, Lonsd. -						×		×			
					C. Grayi, M'Edw. -											
					C. Siluriense, Lonsd. -								×			
		×	×	×	*Favosites aspera*, D'Orb.						×	×	×			
		×		×	*F. cristata*, Blum. -								×			
	×	×	×	×	*F. fibrosus*, Goldf. - -					×	×	×	×			
					F. Forbesii, M'Edw. -											
		×	×	×	*F. gothlandica*, Fougt. -						×		×			
					F. Hisingeri, M'Edw. -											
		×	×	×	*F. multipora*, Lonsd. -						×		×			
		×			*F. regularis?* M'Coy -											?
					Fistulipora decipiens, M'Coy.											
					Goniophyllum Fletcheri, M'Edw.											
				×	*G. pyramidale*, His. -								×			
	×	×	×	×	*Halysites catenularia*, Linn.						×	×	×			
		×	×		*H. escharoides* - -											
					Heliolites discoideus, Lonsd.											
					H. Grayi, M'Edw. -							×				
		×	×	×	*H. interstincta*, Linn. -					×	×	×	×			
		×	×	×	*H. megastoma*, M'Coy -					×			×			
					H. Murchisoni, M'Edw. -					×						
		×	×	×	*H. tubulata*, Lonsd. -					×	×	×				
				×	*Labecheia conferta*, Lonsd.								×			
					Monticulipora Bowerbankii, M'Edw.											
					M. Fletcheri, M'Edw. -						×					
		×			*M. papillata*, M'Coy -											
					M. pulchella, M'Edw. -											
		×	×	×	*Omphyma turbinata*, Fougt.						×		×			
					O. subturbinata, D'Orb. -					×		×				
					O. Murchisoni, M'Edw. -						×					
			×	×	*Palæocyclus porpita*, Linn.											
					P. Fletcheri, M'Edw. -											
					P. rugosus, M'Edw. -											

—	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species. / Wenlock Species, showing Range and value of the Group.	Upper Silurian.											
						Wenlock.								Pass to Ludlow.			
						Lower.			Upper.	Districts.							
						Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Wenlock Series.	North Wales.	South Wales.	Scotland.	Ireland.	Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	
ACTINOZOA—*cont.*			×	×	*P. præacutus*, Lonsd.	—		—	—		×			—	—		?
		×	×	×	*Petraia bina*, Lonsd.	—		—	—	×	×		×	—	—		
		×	×	×	*P. elongata*, Phill.	—		—	—								
		×	×	×	*P. sub-duplicata*, M'Coy	—	—	—	—	×		×					
		×	×	×	*Plasmopora patelliformis*, Lonsd.			—	—		×		×				
					P. scita, M'Edw.				—								
					Strombodes diffluens, M'Edw.				—								
					S. Murchisoni, M'Edw.				—				×				
					S. Phillipsi, D'Orb.				—								
				×	*Syringopora bifurcata*, Lonsd.			—	—		×		×	—			
					S. cæspitosa? Lonsd.				—								
				×	*S. fascicularis*, Linn.				—		×						
			×	×	*S. Lonsdaleiana?* M'Coy				—				×				
				×	*S. serpens*, Linn.		—	—	—	×	×		×	—		—	
		×			*Syringophyllum organum*, Linn.				—								
					Thecia Grayana, M'Edw.				—								
					T. Swindernana, Goldf.			—	—								
					Zaphrentis? lata, M'Coy				—								
				×	*Ptychophyllum patellatum*, Schloth.			—	—				×				
ECHINODERMATA.*		×		×	*Actinocrinus pulcher*, Salt.		—	—	—	×				—	—	—	
					A. Wynnei? Baily				—				×				
					A. retiareus, Phill.				—								
					Apiocystites pentrematoides, Forbes.				—								
					Atelocystites Fletcheri, Salt.				—								
					Bdelacoma vermiformis, Salt.				—								
					Cheirocrinus serialis, Aust.				—								
					C. abdominalis, Salt.				—								
					C. Fletcheri, Salt.				—								
					C. gradatus, Salt.				—								
					Cophinus dubius, König				—								
					Crotalocrinus rugosus, Miller.				—								
					Cyathocrinus arthriticus, Phill.				—								
					C. capillaris, Phill.				—		×						
					C. Dudleyensis, Aust.				—								
					C. goniodactylus, Phill.				—								
					C. arboreus, Salt.				—								
					C. decadactylus, Salt.				—								
					C. monile, Salt.				—								
					C. nodulosus, Salt. MS.				—								
					C. punctatus, His.				—								
					C. quincucialis, Salt.				—								
					C. quinquangularis, Phill.				—								
					C. scoparius, Salt.				—								
					C. squamiferus, Salt.				—								
					C. pyriformis, Phill.				—								
					Dimerocrinus decadactylus, Phill.				—		×						
					D. uniformis, Salt.				—								
					D. icosidactylus, Phill.				—		×						
					D. multiplex, Salt.				—								
					Ennalocrinus punctatus, His.				—								
					E. scriptus, His.				—								
					Eucalyptocrinus decorus, Phill.				—								
					E. granulatus, Lewis				—								
					E. (Hypanthocrinus) polydactylus, M'Coy.			—	—		×						

* These are nearly all Dudley species.

—	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species. Wenlock Species, showing Range and value of the Group.	Upper Silurian. Wenlock. Lower. Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Upper. Wenlock Series.	Districts. North Wales.	South Wales.	Scotland.	Ireland.	Pass to Ludlow. Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
ECHINODERMATA—*cont.*					*Eucladia Johnsoni*, H. Woodw.											
					E. mespeliformis, Goldf.											
					Glyptocrinus expansus, Phill.											
					Herpetocrinus Fletcheri, Salt.											
					Ichthyocrinus pyriformis, Phill.											
					I. Bacchus, Salt.											
					I. McCoyanus, Salt.											
					Lepidaster Grayii, Forbes											
					Marsupiocrinus cælatus, Phill.											
					Mariacrinus flabellatus, Salt.											
				×	*Pereichocrinus moniliformis*, Mill.						×					
					P. limonium, Salt.											
					P. articulosus, Aust.											
					P. simplex, Salt.											
					Pisocrinus ornatus, Kon.											
					P. pilula, Kon.											
					Platycrinus retiarius, Phil.											
					Prunocystites Fletcheri											
					Pseudocrinites bifasciatus											
					P. magnificus, Forbes											
					P. oblongus, Forbes											
					P. quadrifasciatus, Pearce											
					Tetramerocrinus formosus, Aust.											
					Rhophalocoma pyrotechnica, Salt.											
					Sagenocrinus giganteus											
					Taxocrinus tesseraconta-dactylus, His.											
					T. gramulatus, Salt.											
					T. marmoratus, Salt.											
					T. nanus, Salt.											
					T. simplex, Phill.											
					T. tuberculatus, Mill.											
					Echinoencrinites armatus											
					E. baccatus, Forbes											
ANNELIDA		×	×	×	*Cornulites serpularius*					×	×					
					Crossopodia lata, M'Coy						×					
					Helminthites											
	×	×			*Serpulites dispar*, Salt.					×						
					S. longissimus, Murch.											
					S. perversus, M'Coy											
					S. curtus, Salt.						×					
				×	*Spiriobis Lewisii*, Sow.						×	×	?			
		×	×	×	*Tentaculites anglicus*					×	×					
			×	×	*T. ornatus*					×	×					
					Trachyderma squamosa											
					Eunicetes 7 sp.											
					Ænonites 7 „											
					Arabellites 7 „											
					Lumbriconerites 1 „				24							
					Staurocephalites 1 „											
					Nereidavus 1 „											
CRUSTACEA				×	*Turrilepas Grayanus*											
					T. Wrightianus, D'Kon.											
					Acidaspis Barrandii, Flet.							×				
		×	×	×	*A. Brightii*						×					?
					A. coronatus, Salt.											
					A. crenatus, Emm.											
					A. dama, Fl. and Salt.						×					
					A. dumetosa, Fl. and Salt.											

	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species.	Upper Silurian.												
						Wenlock.									Pass to Ludlow.		
						Lower.			Upper.	Districts.							
					Wenlock Species, showing Range and value of the Group.	Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Wenlock Series.	North Wales.	South Wales.	Scotland.	Ireland.	Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
CRUSTACEA—*cont.*					*A. quinquespinosa*, Fl. & Salt.											
					Æchmina clavulus, Jon. and Hall.											
					Æ. cuspidata, J. and H.											
		×			*Ampyx parvulus*, Forbes											
		×		×	*Beyrichia Klædeni*, M'Coy	—				×	×	×				—
					B. interamedia, Jon. and Hall.											
					Bronteus laticauda? Wahl.											
	×	×	×	×	*Calymene Blumenbachii*	—	—	—		×	×			—		—
		×	×	×	*C.*, var. *Allportiana*, Salt.			—					×	—	—	—
	×	×	×	×	*C. brevi capitata*, Portl.			—						—	—	—
					C. Davisii, Salt.									—		
					C. tuberculosa, Salt.									—		
					Ceratiocaris Ludensis											
					C. Murchisoni, M'Coy											
		×		×	*Cheirurus bimucronatus*	—					×		×			—
					Cythere corbuloides, J. and H.											
					C. Grindrodiana, Jones			—								
					Cytherellina siliqua, Jones			—							—	—
					C., var. *tersa*, Jones											
					C., var. *ovata*, Jones											
		×		×	*Cyphaspis megalops*, M'Coy.									—		
		×			*C. pygmæus*, Salt.											
					Bairdia Phillipsiana, J. and H.											
					Deiphon Forbesii, Barr.											
		×	×	×	*Encrinurus punctatus*		—			×	×		×	—		—
					E. variolaris, Brong.								×	—		
					Eurypterus punctatus, Salt.			?						—		—
					Hemiaspis horridus, H. Wood.											
					Homalonotus cylindricus, Salt.			—								
					H. delphinocephalus, Green.			—			×			—	—	—
					H. Johanis, Salt.						×					
					H. Knightii, Konig									—		—
				×	*Illænus Barriensis*, Murch.			—			×					
					I. carinatus, Salt.											
					I. insignis, Hall.											
			×	×	*I. Thomsoni*, Salt.	—										
					Lichas anglicus, Beyr.						×			—		
					L. Barrandii, Fletcher											
					L. Grayii, Fletcher											
					L. hirsutus, Fletcher											
					L. Salteri, Fletcher											
					L. verrucosus, Eicher			—								
	×	×	×	×	*Phacops caudatus*	—	—	—		×	×		×	—	—	—
				×	*P. constrictus*, Salt.			—						—	—	—
					P. Downingiæ, Murch.	—	—	—		×	×					—
					P. longi-caudatus, Murch.			—			×					
					P. Muscheni, Salt.			—								
				×	*P. nudus*, Salt.			—					×			
				×	*P. obtusicandatus*, Salt.			—								
			×	×	*P. Stokesii*, M'Edw.	—		—		×	×	×	×	—		—
					Primitia excavata, J. & H.			—								
					P. lenticularis, J. & H.			—								
					P. cristata, Jones											
					P. concinna, Jones											
					P. mundula, Jones											
					P. pusilla, Jones											
					P. renulina, Jones											
					P. Römeriana, Jones											
					P. seminulum, Jones					×						—
					P. tersa, Jones											
					P. trigonalis, Jones											

	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species. / Wenlock Species, showing Range and value of the Group.	Upper Silurian. Wenlock. Lower. Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Upper. Wenlock Series.	Districts. North Wales, sp.	South Wales.	Scotland.	Ireland.	Pass to Ludlow. Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
CRUSTACEA—*cont.*					*P. umbilicata*, Jones											
					P. variolata, Jones											
				×	*Proetus latifrons*, M'Coy						×		×			
				×	*P. Stokesii*, Murch.											
					Pterygotus problematicus											
		×			*Sphærexochus mirus*, Bey.											
					Thilipsura corpulenta											
					T. tuberosa, J. & H.											
					T. V. scripta, J. & H.											
		×		×	*Staurocephalus Murchisoni*, Barr.											
BRYOZOA					*Cellepora favosa*, Goldf.											
					Ceriopora abnormis											
					C. affinis, Goldf.											
					C. granulosa, Goldf.											
					C. oculata, Goldf.											
					Diastopora consimilis						×					
					D. irregularis, Lonsd.											
					Discopora antiqua, Lamk.											
					D. favosa, Lonsd.											
					D. squamata, Lonsd.											
					Escharina angularis Lonsd.											
				×	*Fenestella assimilis*, Lonsd.											
					F. Lonsdalei, D'Orb.											
		×			*F. Milleri*, Lonsd.											
					F. patula, M'Coy											
					F. reticulata, Lonsd.											
					F. rigidula, M'Coy											
					F. Scalpellum, Lonsd.											
		×	×	×	*F. sub-antiqua*, D'Orb.											
		×			*Glauconome disticha*, Goldf.											
					Heteropora crassa, Lonsd.											
					Polypora crassa, Lonsd.											
		×	×	×	*Ptilodactya lanceolata*						×		×			
					Retepora infundibulum											
BRACHIOPODA*					*Athyris compressa*, Sow.							×				
					A. depressa, Sow.											
					A. obovata, Sow. (*Glassia*)											
					Atrypa Barrandii, Dav.											
					A. Grayii, Dav.						×					
		×	×	×	*A. imbricata*, Sow.											
		×	×	×	*A. marginalis*, Daim.						×					
			×	×	*A. reticularis*, Linn.	—	—	—	—	×	×	×	×	—	—	—
		×		×	*Chonetes lepisma*, Sow.		—			×						
				×	*C. striatella*, Dalm.		—			×	×		×			
		×		×	*C. lævigata*, Sow.					×	×					
				×	*C. minima*, Sow.	—	—			×				—		
					Crania Grayi, Dav.											
			×		*C. implicata*, Sow.	—					×		×			
					C. Sedgwickii, Lewis											
					C. Siluriana, Dav.											
					Cyrtia nasuta, Linds.											
					Discina Morrisii, Dav.											
					D. rugata, Sow.						×					
					D. striata, Sow.											
					D. Verneuilii, Dav.											
					Eichwaldia Capewellii											
					Glassia Elongata											
					Leptæna orbigniana, Dav.											
					L. segmentum, Ang.											
	×	×	×	×	*Lericea*, Sow.											
					L. lævigata, Sow.											
				×	*L. transversalis*, Wahl.	—	—	—	—	×	×	×	×	—	—	—

* Those species in the Wenlock column are nearly all from Dudley and Wenlock edge.

—	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species. / Wenlock Species, showing Range and value of the Group.	Upper Silurian. Wenlock. Lower. Tarannon Beds.	Denbighshire Grits.	Woolhope Beds.	Upper. Wenlock Series.	Districts. North Wales, sp.	South Wales.	Scotland.	Ireland.	Pass to Ludlow. Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
Brachiopoda —*cont.*				×	*Lingula Lewisii*, Sow. -					×	×					
				×	*L. striata*, Sow. -											
					L. Symondsii, Salt. -	—					×					
				×	*Meristella circe*, Barr. -											
					M. didyma, Dalm. -					×	×		×			
					M. nitida, Hall. -											
					M. Maclareni, Hasw. -							×				
					M. tumida, Dalm. -			—			×	×				
					M. Mawei, Dav. -											
					Nucleospira pisum, Sow.							×				
					Obolus Davidsoni, Salt. -								×			
					O. transversus, Salt. -											
					O. Woodwardii, Salt. -											
					Orbiculoidea Beckettiana											
					O. Forbesii, Dav. - -						×					
					Orthis æquivalvis, Dav. -											
					O. basalis, Dalm. - -											
	×	×	×	×	*O. biforata*, Scloth. -						×					
		×	×	×	*O. biloba*, Linn. -	—					×	×				
			×	×	*O. Bouchardii*, Dav. -											
	×	×	×	×	*O. calligramma*, Dalm. -						×		×			
					O. crassa, Linds. -											
					O. Edgelliana, Salt. -						×					
	×	×	×	×	*O. elegantula*, Dalm. -	—		—		×	×	×	×			—
					O. hybrida, Sow. - -	—										
					O. Lewisii, Dav. - -							×				
					O. Hughesii, Dav. -											
				×	*O. polygramma*, Sow. -							×				
			×	×	*O. Mullockensis* } Dav. -				?			×				
					O., var. of *reversa* }											
				×	*O. rustica*, Sow. - -								×			
				?	*Pentamerus galeatus* -						×		×			
					P. Knightii, Sow. - -								×			—
					P. linguifera, Sow. -											
					Poblongus var. *lævis* -						×					
				×	*P. rotundus*, Sow. -	—										—
				×	*P. undatus*, Sow. - -								×			
					Retzia Barrandii, Dav. -											
					R. Salteri, Dav. - -											
				×	*Rhynchonella Beltiana* -								×			
					R. Dayi, Dav. - -											
		×	×	×	*R. borealis*, Scloth. & vars.		—	—		×	×	?	×			
			×	×	*R. cuneata*, Dalm. -		—	—		×	×					
				×	*R. decemplicata*, Sow. -	—	—		?	×	×					
					R. deflexa, Sow. - -								×			
					R. Lewisii, Dav. - -											
					R. navicula, Sow. - -		—	—		×	×		×			—
			×	×	*R. nucula*, Sow. - -	—	—	—		×	×	×	×			—
					R. Stricklandi, Sow. -						×		×			
				×	*R. Wilsoni*, Sow. - -					×	×	×	×			
					Siphonotreta anglica, Mor.											
					Spirifera bjugosa, M'Coy								×			
				×	*S. crispa*, His. - -		—	—		×	×	×	×			
				×	*S. elevata*, Dalm. - -	—	—	—		×	×		×			—
				×	*S.* (*Cyrtia*) *exporrecta* -	—	—	—			×	×				
			×	×	*S. plicatella*, Linn. -		—	—			×		×			
					S., var. *globosa*, Salt. -											
			×	×	*S.*, var. *radiata*, Salt. -											
					S. sulcata, His. - -											
			×	×	*Stricklandinia lirata*, Sow.						×					
		×	×	×	*Strophomena antiquata* -							×	?			
			×	×	*S. applanata*, Salt. -							×	×			—
					S. Dayi, Dav. - -								×			
			×	×	*S. euglypha*, His. -					×	×		×			
		×		?	*S. funiculata*, M'Coy -			—		×	×		×			
					S. filosa, Sow. - -					×	×		×		—	
					S. Fletcheri, Dav. -											
					S. Hendersoni, Dav. -							×				
				×	*S. imbrex*, Pander -						×					
					S. Orbignyi, Dav. -											
					S. Ouralensis, Vern. -						×					

—	Llandeilo.	Caradoc.	Lower Llandovery.	Upper Llandovery.	Wenlock Species. Wenlock Species, showing Range and value of the Group.	Upper Silurian. Wenlock. Lower. Tarannon Beds.	Dunbighshire Grits.	Woolhope Beds.	Upper. Wenlock Series.	Districts. North Wales, sp.	South Wales.	Scotland.	Ireland.	Pass to Ludlow. Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.
BRACHIOPODA —*cont.*		×	×	×	*S. compressa*, Sow. -						×		×			
		×	×	×	*S. pecten*, Linn. -					×	×	×	×			
					S. Walmstedii, Linds.											
	×	×	×	×	*S. rhomboidalis*, Wilck. -					×	×	×	×			
					S. Waltoni, Dav. - -											
					Striptoshynchus nasuta, Linst.											
					Triplesia MacCoyana, Dav.											
					Waldheimia Mawei, Dav.											
					W. Glassei, Dav. - -											
LAMELLIBRANCHIATA.					*Ambonychia acuticotsa* -					×						
					A. tumida, Sollas - -						×					
					Avicula ampliata, Phill. -						×					
					A. Danbyi, M'Coy -											
					Pterinæa asperula, M'Coy											
				×	*P. demissa*, Conrad -											
					P. laminosa, Goldf. -											
					P. lineata, Goldf. - -						×		×			
					P. posidoniæformis, M'Coy						×					
				×	*P. planulata*, Conrad -						×		×			
					P. mira? - - -											
		?	×	×	*P. retroflexa*, Wahl. -					×	×		×			
				×	*P. Sowerbyi*, M'Coy -						×					
				×	*P. subfalcata*, Conrad -					×						
		×			*P. tenuistriata*, M'Coy -						×					
					Anodontopsis perovalis -											
		×			*Arca* (*Palæarca*) *Edmondiiformis*, M'Coy.					×	×					
				×	*A. subæqualis*, M'Coy -						×					
					Cardiola fibrosa, Sow. -					×	×		×			
	×	×	×	×	*C. interrupta*, Brod. -					×	×		×			
		×		×	*C. striata*, Sow. - -					×	×					
					Cleidophorus planulatus											
		×			*Ctenodonta anglica*, D'Orb					×	×					
				×	*C. lingualis*, Phill. -											
				×	*C. sulcata*, His. - -						×					
		×		×	*Cucullella antiqua*, Sow.					×	×					
					C. Cawdori, Sow. - -						×					
					C. coarctata, Phill. -					×						
				×	*C. ovata*, Sow. - -					×						
				×	*Goniophora cymbæformis*					×	×		×			
					Grammysia cingulata -						×					
					Lunulacardium aliforme					?						
		×		×	*Modiolopsis antiqua*, Sow.											
					M. acutipora, Sollas -						×					
					M. complanata, Sow. -											
		×		×	*M. gradata*, Salt. - -						×					
					M. Nilssoni, His. - -											
					M. inflata, var. *elevata* -						×					
					Mytilus chemungensis, Con.					×	×					
		×	×	×	*M. mytilimeris*, Conrad -						×					
					M. unguiculatus, Salt. -					×	×					
				×	*Orthonota amydalina* -											
					O. decepiens, M'Coy -							×				
					O. inornata - -						×	?				
					Pleurorhynchus æquicostatus, Phill.											
GASTEROPODA					*Acroculia haliotis*, Sow. -					×	×		×			
					A. prototypa, Phil. -						×					
					Cyclonema corallii, Sow.								×			
					C. octavia, D'Orb. -											
					C. simplex, Sollas -						×					
					C. ventricosa, Hall. -											
					C. angulatum, Sollas -						×					
					Eunema cirrhosum, His.						×					
		×		×	*Euomphalus alatus*, Sow.						×		×			
					E. carinatus, Sow. -					×						

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GASTEROPODA —*cont.*				×	*E. discors*, Sow. - -											
				×	*E. fimbriatus*, Sow. - -											
					E. rugosus, Sow. - -											
			×	×	*E. sculptus*, Sow. - -											
					Holopella gracilior, M'Coy											
					H. hydrepica, Sollas -											
				×	*H. obsoleta*, Sow. - -											
					H. sinuata, Sollas - -											
					Loxonema elegans, M'Coy											
				×	*L. sinuosa*, Sow. - -											
				×	*Murchisonia articulata* -											
					M. corpulenta, Sollas -											
					M. bilineata, Phill. -											
					M. elegans, Sollas - -											
					M. Lloydii, Sow. - -											
					Trochus (Cyclonema) cælatulus, M'Coy.											
			×	×	*Turbo triporquatus*, M'Coy											
PTEROPODA -			×	×	*Conularia Sowerbyii* Def.											
			×		*Theca anceps*, Salt. -											
					T. Forbesii, Sharpe -											
HETEROPODA					*Eccyliomphalus lævis*, Sow.											
		×	×	×	*Bellerophon bilobatus*, Sow.											
				×	*B. dilatatus*, Sow. -											
				×	*B. trilobatus*, Sow. -											
				×	*B. expansus*, Sow. -											
				×	*B. Wenlockiensis*, Sow. -											
				×	*B. carinatus*, Sow. -											
				×	*B. subplicostatus*, M'Coy											
CEPHALOPODA					*Tetragoceras lævigatum* -											
					T. Wrightii, Sow. - -											
				×	*Actinoceras annulatum*, Sow. -											
					Lituites articulatus, Sow.											
			×	×	*L. Riddellii*, Sow. -											
			×	×	×	*L. Cornu-arietis*, Sow. -											
						L. giganteus, Sow. -										
						L. tortuosus, Sow. -										
			×		×	*Orthoceras angulatum* -										
						O. annulatum, Sow. -										
						O. attenuatum, Sow. -										
						O. bullatum, Sow. -										
						O. canaliculatum, Sow. -										
						O. circulare, Sow. -										
					×	*O. conicum*, Sow. -										
						O. distans, Sow. -										
						O. Ludense, Sow. -										
						O. Maclareni, Salt. -										
						O. Marloense, Phill. -										
						O. Mocktrense, Sow. -										
						O. (Ceroceras?) primævum										
				×		*O. sub-gregarium*, M'Coy										
				×		*O. sub-undulatum*, Portl.										
				×	×	*O. tenuicinctum*, Portl. -										
						O. trochleare, Sow. -										
						O. (Ceroceras?) ventricosum										
						Phragmoceras pyriforme										
				×		*P. nautileum*, Sow. -										
					×	*P. ventricosum*, Sow. -										
						Cycloceras ibex, Sow. -										

LUDLOW ROCKS.

Although no true Ludlow rocks are certainly known in North Wales, excepting in a small part of Montgomeryshire, south and east of Newtown, I deem it necessary to briefly notice the species which occur in the Ludlow formation, especially as in South Wales we have 163 species, Westmoreland 127, Ireland 32. The whole known fauna represents 392 species, of which 222 occur in the Lower Ludlow, 84 in the Aymestry Limestone, and 260 in the Upper Ludlow. Of these 260 Ludlow species, 155 pass up from the Wenlock group. The Vertebrata first appear in the Ludlow beds, 13 of the 14 known fishes being Upper Ludlow, the single species (*Scaphodus Ludensis*) first occurring in the Aymestry Limestone.

The entire fauna, eliminating the four plantæ, consists of 388 species, the 14 classes yielding the following census:—

	Species.
Protozoa	10
Hydrozoa	8
Actinozoa	17
Echinodermata	21
Annelida	17
Crustacea	97
Polyzoa	3
Brachiopoda	48
Lamellibranchiata	71
Gasteropoda	33
Pteropoda	3
Heteropoda	7
Cephalopoda	37
Pisces	14
	388

The Ludlow group, as before stated, is allied to the Wenlock through 155 species. The chief classes in the Ludlow, as testified by numbers of forms, as seen above, are the Echinodermata, the Crustacea, Brachiopoda, Lamellibranchiata, Gasteropoda, Cephalopoda, and Fishes, all of which are largely represented. Few or no species pass to the Devonian, or Old Red Sandstone; those that unite the two horizons are Fishes.

The small Aymestry Limestone fauna, although local, is a remarkable one, and clearly shows the nature of the sea and sea bed with relation to the habits of life of the several groups now represented; most also are Wenlock. In the Protozoa 5 species occur; the Actinozoa 8 out of 17 known in the Ludlow; the Echinodermata 3; the Annelida 4 (3 are Wenlock); Crustacea only 11 species out of 97 occurring, 6 only being *Trilobita*. *Ptilodictya lanceolata* is the only Bryozoon. The Brachiopoda number 48 species, and of these 25 are Aymestry only. Seven out of the 71 Ludlow Lamellibranchiata occur in the Aymestry Limestone, yet out of 33 Gasteropoda 11 are Aymestry, thus definitely showing, with the other groups, the deeper sea character of the Aymestry fauna. Of the 37 Cephalopods, only 6 are known, and, as before stated, only? 1 species of Fish, whereas the Upper Ludlow beds contain 14.

R. E.

Distribution of the Ludlow Species.

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.*							
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.
Plantæ		*Actinophyllum plicatum.*			×	×				×		×		
		Chondrites versimilis.			×	×							+	
		Fucoides gracilis?			×						×			
		Pachytheca sphærica.			×	×				×	×	?		
		Pachysporangium pilula, Salt. MS.				×				×		×		
Protozoa		*Amphispongia oblonga.*			×					?		×		
		Cliona prisca -	×	×							×	?		
		Favospongia Euthveni.			×				×					
	×	*Ischadites Kœnigii*	×	?	×					×	×			
	×	*Stromatopora striatella.*	×	×						×	×	×		
		Spongarium æquistriatum.		×	×				×					
	×	*S. Edwardsii* -	×		×			×		×	×	×		
		S. interlineatum -		×	×				×					
		S. interruptum -		×	×				×					
		Tetragonis Danbyi.			×				×					
Cœlenterata Actinozoa.	×	*Alveolites La Bechii.*	×				×			×	×	×		×
	×	*Cœnites intertextus,* Eichw.		×										
	×	*Cyathaxonia siluriensis.*	×		×				×					
	×	*Cyathophyllum truncatum.*	×	×						×	?	?		×
	×	*Favosites aspera*	×	×	×		×			×	×	×		×
	×	*F. cristata* -	×						×	×				×
	×	*F. fibrosa* - -	×		×		×		×	×	×	?		×
	×	*F. Gothlandica* -	×				×			×	×	×		
	×	*F. Forbesii* -	×		×									
	×	*Fistulipora decipiens.*	×	×										
	×	*Halysites catenularia.*	×				×		×	×	×	?		
	×	*Heliolites interstinctus.*	×	×			×		×	×	×	×		
	×	*H. tubulatus* -	×	×			?	×	?	×	×	×	×	
	×	*Monticulipora papillata.*	×	×			×		×		×	×		
	×	*Omphyma turbinata.*	×		?					×	×	×		×
	×	*Petraia bina* -	×	×			×				×			
	×	*Syringopora bifurcata.*	×				?			×	×			
	×	*S. serpens* - -	×		×		×			×	×			
Echinoder-mata.	×	*Actinocrinus pulcher.*	×	×	×			×	×					×
		Echinocystites pomum.	×							×				
		E. uva - -	×											
	×	*Ichthyocrinus pyriformis.*	×	×	×				×		×			
	×	*I. M'Coyanus* -	×			×		×						
		Palæster hirudo -			×				×					
		P. Ruthveni -		×	×				×					
		Palæasterina primæva.	×	?	×				×					
		Palæocoma Colvini.	×							×				

* Many species occur in Monmouthshire and Gloucestershire, &c., but the columns would be too numerous for all localities not required for comparison.

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.							
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.
ECHINODERMATA—*cont.*		*P. cygnipes* -	×							×				
		P. Marstoni -	×							×				
		P. vermiformis -	×							×				
		Taxocrinus ? D'Orbignyi.	×		×				×					
		Pelæodiscus ferox, Salt.	×							×				
		Protaster leptosoma.	×											
		P. Miltoni -	×							×				
		P. Sedgwickii -	×		×				×					
	×	*Pseudocrinites magnificus.*	×				×				×			
	×	*P. quadrifasciatus*	×								×			
	×	*Rhopalocoma pyrotechnica.*	×							×				
		Pelæodiscus ferox, Salt.	×							×				
ANNELIDA	×	*Cornulites serpularius.*	×	×	×	×	×	×	×		×	×	×	
	×	*Helminthites*, sp. -	×						?					
	×	*Serpulites dispar*	×		×		×	×	×	×				
	×	*S. longissimus* -	×	×	×	×	×		×	×	×	×		
	×	*Spirorbis Lewisii*	×		×		×			×	×		×	
	×	*Tentaculites anglicus.*			×		×	×	×	×		×		
	×	*T. ornatus* - -		×	×		×	×			×		×	
		T. tenuis - -		×	×		×		×					
		Trachyderma coriacea.			×					×	×	×		
	×	*T. squamosa* -	×		×		×		×		×	×		
		Œnonites, 3 sp. -			×									
		Arabellites, 3 sp. -			×									
	×	*Crossopodia lata*, M'Coy.				×	×							
CRUSTACEA	×	*Acidaspis coronatus.*	×				×	×		×	×	×		
		Astacoderma -			14									
	×	*Beyrichia Klædeni.*			×	×	×		×	×		×	×	
		B. Wilckensiana -	×		×							×		
	×	*Calymene Blumenbachii.*	×	×	×		×		×	×		×		×
	×	*C. Allportiana* -	×	×	×					×		?		
	×	*C. tuberculosa* -	×		×		×		×	×				
		Ceratiocaris cassia.	×							×				
		C. decorus -			×	×	×				×			
		C. ellipticus -	×		×			×	×					
		C. ensis - -	×							×				
		C. gigas - -	×								×	×		
		C. inornatus -		×	×				×					
		C. leptodactylus -	×		×					×				
	×	*C. Ludensis* -	×							×				
	?	*C. Murchisoni* -	×		×				×	×				
		C. papilio - -	×		×							×	×	
	?	*C. robustus* -	×							×				
		C. solenoides -			×				×	×				
		C. stygius - -	×		×							×	×	
		C. vesica - -	×							×				
	×	*Cheirurus bimucronatus.*	×	×			×		×	×	×	×		
	×	*Cyphaspis megalops.*	×							×	×	?		
	×	*Cytherellina siliqua.*		×	×					×	×	?		
	×	*Deiphon Forbesii*	×								×	×		
		Dictyocaris Ramsayi.	×										×	

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.							
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.
CRUSTACEA — *cont.*		*D. Slimoni* -			×							×		
		Cypridina, sp. -	×	×	×								×	
	×	*Encrinurus punctatus.*	×		×		×				×			
	×	*E. variolaris* -	×								×			
		Entomis divisa -			×		×				×	×		
		E. impendens -			×								×	
		E. tuberosa -			×								×	
		Eurypterus abbreviatus.			×	×	×					×		
	?	*E. Scorpioides* -		×								×	×	
		E. Brodiei - -				×								
		E. acuminatus -		×	×	×				×				
		E. cephalaspis -	×		×				×					
		E. chartarius -			×								×	
		E. lanceolatus -			×							×		
		E. linearis -			×	×	×			×		×		
		E. obesus - -			×							×	×	
	×	*E. punctatus* -	×		×				×	×				
		E. pygmæus -	×		×	×	×			×	×	×	×	
		Hemiaspis limuloides.	×		×					×		×		
	×	*H. optatus* - -	×							×				
		H. speratus -	×							×				
		H. Salwayi -	×		×					×		×		
		H. tuberculatus -	×		×					×	×			
		Himantopterus maximus.			×	×				?				
	×	*Homalonotus delphinocephalus.*	×	×			×			×	×			
	×	*H. Knightii* -	×		×		×	×	×	×		×		
		H. Ludensis -			×					×				
		Kirkbya fibula -			×						×			
		Moorea silurica -			×						×			
	×	*Lichas anglicus* -	×				×			×	×			
		Leperditia marginata.			×	×				×	×	×		
		Neolimulus falcatus.			×								×	
		Necrogammarus Salwayi.			×					×				
	×	*Phacops caudatus*	×	×	×		×	?	×	×	×	×		×
	×	*P. longicaudatus*, Murch.	×				×			×				
	×	*P. constrictus* -	×	?	×		×			×	×	×		
	×	*P. Downingiæ* -	×		×		×		×	×	×	×		
	×	*P. Stokesii* -	×				×			×	×	×	×	
		Primitia ovata -	×	×										
	×	*P. seminulum* -			×	×								
	×	*P. umbilicata* -	×	×						×				
	×	*Proetus latifrons*	×			×	×		×		×	×		
	×	*P. Stokesii* -	×								×	×		
		Pterygotus arcuatus.	×		×	×				×	×	×		
		P. bilobus and 4 vars.			×					×			×	
		P. Banksii -			×	×				×		×		
		P. gigas - -			×	×						×		
		P. Ludensis -			×	×				×	×			
		P. perornatus -			×								×	
	?	*P. problematicus*			×	×			×	×		×	×	
		P. raniceps -	×		×								×	
		P. stylops - -			×							×		
		Slimonia acuminata.			×								×	
		S. punctata, Salt.	×							×				
		S. scorpioides -			×									
		Stylonurus Logani			×								×	
		S. megalops -			×	×	×			×				
		S. Powrisi, Page -			×	×							×	
		Turrilepas Grayanus, Deklon.	×											
		Parka decepiens, Fleury.			×					×				

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.								
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.
HYDROZOA & BRYOZOA.	×	*Monograptus priodon.*	×		×		×	×	×	×		×	×	
		M. Flemingi, Salt	×							×			×	
		M. Colonus, Barr.-	×						×	×				
		Monograptus leintwardensis, Hop.	×				×			×				
	×	*Heteropora crassa*	×	×							×			
		Ceriopora sculata, Goldf.	×							×				×
	×	*Ptilodictya lanceolata.*	×	×						×	×	×		
	×	*Ptilograptus anglicus.*	×							×				
BRACHIOPODA	×	*Athyris compressa?*	×										×	
		A. obovata -	×							×	×	×		
	×	*Atrypa reticularis.*	×	×	×		×		×	×	×	×	×	×
	×	*Chonetes lepisma* -	×	×						×	×	×		
	×	*C. striatella* -	×	×	×	×	×		×	×	×	×	×	×
	×	*C. minima* - -	×				×			×				
	×	*Crania implicata*	×	×	×		×			×	×	×	×	×
	×	*Discina Morrisii*	×	×						×				
	×	*D. rugata* - -	×	×	×	×	×		×	×	×	×		
	×	*D. striata* - -			×		×		×	×				
	×	*Leptæna transversalis.*	×	×		×	×			×				
		Lingula cornea -	×	×	×	×	×		×	×	×	×		?
		L. lata - -	×	×	×				×	×			×	
	×	*L. Lewisii* - -	×	×	×		×			×	×	×		×
	×	*L. striata* - -	×							×				
	×	*L. minima* -	×		×	×				×	×	×		
	×	*L. Symondsii* -	×											
	×	*Meristella didyma*	×	×	×		×			×	×	×		
	×	*M. Maclareni*, Hasw.											×	
	×	*M. tumida* -	×	×	×		×			×	×	×		
	×	*Orthis biloba* -	×							×	×	×		
		O. canaliculata -		×										
	×	*O. crassa* - -	×								×			
		O. lunata, Sow. -			×		×		×	×	×	×		
	×	*O. elegantula* -	×		×		×			×	×	×	×	
	×	*O.*, var. *orbicularis.*			×		×			×	×	×		
	×	*O., hybrida* -	×				×			×	×			
	×	*Pentamerus galeatus.*	×	×			×			×	×			×
	×	*P. rotundus*, Sow.	×									×		
	×	*P. Knightii* -		×	×		×			×				
	×	*Rhynchonella navicula.*	×	×	×		×		×	×	×			
	×	*R. nucula* - -	×	×	×		×		×	×	×	×		
		R. Pentlandica -	×										×	
	×	*R. Stricklandi* -		×			×							
	×	*R. Wilsoni* -	×	×	×		×		×	×	×	×	×	
	×	*Spirifera bijugosa*	×	×	×									
	×	*S. crispa* - -	×	×			×			×	×			
	×	*S. elevata* - -	×	×	×		×		×	×	×			
	×	*S. (cyrtia) exporrecta.*	×							×				
	×	*S. radiata* (var.)	×				×				×			
	×	*S. plicatella* -	×				×				×	×		
	×	*Strophomena antiquata.*	×											
	×	*S. euglypha* -	×	×	×		×			×		×		
	×	*S. pecten* - -		×			×			×			×	
	×	*S. rhomboidalis* -	×		×	×	×		×	×	×	×		
	×	*S. filosa* - -	×		×		×		×	×	×		×	
	×	*S. applanata*, Salt			×		×							
		S. ornatella, Salt -			×									

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.								
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.	
LAMELLIBRANCHIATA.	×	*Ambonychia acuticostata.*	×					×							
	×	*Avicula ampliata*	×		×		×								
		A. antiqua -			×				×			×			
	×	*A. Danbyii* -	×		×		×								
		Pterinæa Boydii-			×										
	×	*P. demissa* -			×	×	×		×						
		P. hians - -		×	×				×			×			
	×	*P. lineata* - -			×		×		×						
		P. megaloba - -			×	×	×								
	×	*P. planulata* -	×				×								
	?	*P. pleuroptera* -	×				×								
	×	*P. retroflexa* -	×		×		×		×			×			
	×	*P. Sowerbyi* -	×	×	×	×	×		×						
	×	*P. subfalcata* -			×		×		×	×					
	×	*P. tenuistriata* -	×		×	×	×		×	×					
	×	*P. posidoniæformis?* M'Coy.	×								×				
		Anodontopsis angustifrons.			×		×		×						
		A. bulla - -			×	? ×	×								
		A. lævis - -			×		×		×						
		A. lucina - -			×								×		
	×	*A. perovalis* - -	×				×			×	×	×			
		A. quadratus -			×	×	×								
		A. securiformis -	×		×		×		×			×			
	×	*Arca Edmondiiformis.*			×		×		×						
		A. primitiva -			×		×		×						
	×	*A. subæqualis* -	?		×	×	×								
	×	*Cardiola fibrosa* -	×							×	×				
	×	*C. interrupta* -	×		×		×		×	×					
	×	*C. striata* - -	×	×			×			×		×			
	×	*Ctenodonta anglica.*	×				×		×						
		C. obesa - -			×								×		
	×	*C. sulcata* - -	×							×					
		C. thracioides -			×								×		
	×	*Cucullella antiqua.*	×		×	×	×							×	
		C. Cawdori -	×				×								
	×	*C. coarctata* -	×		×		×	×	×						
	×	*C. ovata* - -			×	×	×		×			×			
		Dolabra elliptica			×	×	×								
		D. obtusa - -			×	×	×	×							
	×	*Goniophora cymbæformis.*	×		×	×	×		×	×	×		×	×	
	×	*Grammysia cingulata.*	×	×	×			×	×		×				
		G. extrasulcata -	×		×		×		×						
		G. rotundata -			×		×		×						
		G. triangulata -			×	×	×		×						
	×	*Lunulacardium aliforme?*	×							×					
		L. elegans - -			×								×		
		Leda ambigua -	×				×								
	×	*Modiolopsis complanatus.*			×	×	×		×	×			×		
	×	*M. gradata*, Salt -	×		×		×								
		M. lævis - -			×	×	×								
	×	*M. Nilssoni* -	×		×		×				×				
		M. platyphyllus -	?		×	×	×								
		Mytilus exasperatus.	×				×			×					
	×	*M. mytilimeris* -	×		×		×				×	×			
		Orthonota affinis	×		×				×						
	×	*O. amygdalina* -	×		×		×		×	×		×	×		
		O. angulifera -			×	×	×		×						
		O. bulla - -			×								×		
		O. complanata -			×		×		×		×				
		O. decipiens -			×	×	×		×				×		
		O. globulosa -			×				×						
		O. impressa -	×		×					×	×	×	×		
		O. navicula -	×				×								

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.							
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.
LAMELLIBRANCHIATA—*cont.*		*O. prora*			×					×				
		O. rigida	×		?		×				×	?		
		O. rotundata		×	×		×		×	×			×	
		O. semisulcata	×	×	×		×		×	×		×		
		O. undata			×				×	×			×	
		O. solenoides			×	×	×		×					
		O. truncata			×				×					
		Solen rectus?			×									
GASTEROPODA		*Acroculia antiquata.*			×							×	×	
	×	*A. haliotis*, Sow.	×				×							
		A. euomphaloides	×							×				
	×	*Cyclonema corallii*	×	?	×		×		×	×				
		C. turbinatum	×				×							
	×	*C. octavia*		×	×				×	×		×		
		C. quadristriata		×							×			
		C. undifera		×	×							×		
	×	*Euomphalus alatus*	×	×			×			×	×	×		×
	×	*E. carinatus*	×	×	×					×	×	?		
		E. centrifugus	×							×				
	×	*E. funatus*	×	×			×			×	×	×	×	
	×	*E. rugosus*			×									
		Holopella cancellata.			×		×		×					
		H. conica			×	×	×		×					
	×	*H. gracilior*	×					×						
		H. gregaria	×		×	×	×	×	×	×				
		H. intermedia			×				×					
	×	*H. obsoleta*			×	×	×		×					
	×	*Loxonema elegans*	×		×					×				
		L. sinuosa	×	×										
		Murchisonia articulata.	×	?	×				×	×	×	×		
		M. cingulata		×						×				
		M. corallii		×	×		×		×	×	?			
	×	*M. Lloydii*	×	×	×		×		×	×	×	×		
		M. torquata			×	×	×		×					
		Naticopsis parva			×		×		×		×	×		
		Platyschisma helicites.			×	×	×		×			×	×	
		P. simulans			×		×						×	
		P. Williamsi			×	×	×							
		Pleurotomaria crenulata.			×				×					
		P. undata		×			×			×		×		
		P. quadristriata	×								×			
		Naticopsis glaucinoides, Sow.	×						×					
PTEROPODA	×	*Conularia Sowerbyi.*			×				×	×		×	×	
		C. subtilis			×				×					
	×	*Theca Forbesii*	×		×		×		×	×				
	×	*Ecculiomphalus lævis*	×		×		×		×	×	×	×		
HETEROPODA	×	*Bellerophon carinatus.*	?		×	×	×		×					
		B. expansus	×		×	×	×		×	×	×			
		B. Murchisoni			×	×	×		×					
		B. obtectus			×		×							
	×	*B. trilobatus*		×	×	×	×		×	×	×			
	×	*B. dilatatus*	×	?	×					×	×			
CEPHALOPODA		*Ascoceras Barrandii.*	?		×					×		×		
	×	*Lituites articulatus*	×							×	×	×		
	×	*L. Biddulphii*	×									×		
	×	*L. giganteus*	×	×	×					×		×		
	×	*Orthoceras angulatum.*	×	×			×	×	×	×	×	×		
	×	*O. annulatum*	×							×	×	×		
		O. articulatum	×	×	×		×			×		×		

Classes.	Wenlock.	Ludlow Group.	Horizons.				Areas.							
			Lower Ludlow.	Aymestry Limestone.	Upper Ludlow.	Passage Beds.	South Wales.	North Wales.	Westmoreland.	Shropshire.	Worcestershire.	Herefordshire.	Scotland.	Ireland.
CEPHALOPODA —*cont.*		*O. baculforme* -			×				×					
	×	*O. bullatum* -	×		×	×	×		×	×	×	×		
		O. dimidiatum -	×		×		×		×	×		×		
		O. excentricum -	×				×			×				
		O. filosum - -	×						×	×		×		
		O. gregarium -			×					×				
		O. ibex - -			×		×		×	×	×	×		
		O. imbricatum -			×				×	×				
		O. laqueatum -	×						×					
	×	*O. Ludense* -	×		×				×	×				
	×	*O. Maclareni* -			×								×	
	×	*O. Mocktreense* -	×	×	×						×	×		
		O. perelegans -	×		×		×		×	×	×	×		
		O. striato-punctatum.			×									
	×	*O. subgregarium*	×			?	×		×			×		×
	×	*O. subundulatum*	×		×		×	×	×	×	×		×	
		O. tenuiannulatum.	×	×	×				×	×		×		
	×	*O. tenuicinctum* -			×		×		×			×		
		O. textile - -			×		×							
		O. torquatum -			×				×					
	×	*O. tracheale* -	×		×	×	×		×			×		
		Phragmoceras arcuatum.	×							×				
		P. compressum -	×	?						×		×		
		P. intermedium -	×							×				
	×	*P. nautileum* -			×					×				
	×	*P. pyriforme* -	×	?	?		×			×	×			
	×	*P. ventricosum* -	×	×						×	×	×		
		Tretoceras semipartitum.			×	×	×							
		Exosiphonites Edgelli, Salt.	×									×		
		Exosiphonites striolatus, Edgell.	×									×		
PISCES - -		*Auchenaspis Salteri.*			×		×			×				
		Cephalaspis ornatus.			×	×	×			×				
		C. Murchisoni -			×	×	×							
		Eukeraspis pustuliferus, Ag.			×	×				×				
		Plectrodus mirabilis.			×		×			×				
		P. pleiopristis -			×					×				
		Pteraspis Banksii.			×		×							
		P. truncatus -			×	×	×							
		Scaphaspis Ludensis.	×	?	×	×	×			×				
		Thelodus parvidens.			×					×				
		Thysites verrucosus.			×					×				

R. E.

The Upper Silurian rocks of Denbighshire are of great thickness; while it is certain that the lower portion of these strata mostly consist of Wenlock beds, it is uncertain, in the absence of fossils, whether or not part of the upper portion of this series may not belong to the Ludlow rocks.

The conglomerates which occasionally underlie the mountain limestone of Flintshire, according to Sedgwick's observations do not contain any fossils, and may be Lower Carboniferous rather than belong to the Old Red Sandstone.

[Few as are the Wenlock species in North Wales as compared with those of the Wenlock, Ludlow, Dudley, and Woolhope areas, still out of about 530 known species in the Wenlock group we have in the *lower division* of the Wenlocks of North Wales 120 species. Montgomeryshire yields 36 and Carnarvonshire 85 occurrences, and from the same horizon above the Tarannon and Denbighshire grits we have 65 species, all from Denbighshire, and the 13 localities near Llansannan and Llangollen give us 134 occurrences for the distribution of the 65 species named.

The fauna of the Wenlock group in its sub-divisions as now known is given in the table of distribution of the species, pp. 453–461, and also the number of species that pass up from the Wenlock, or are common to the Ludlow group, or which connect the two formations. They number 125. We must, however, remember that the Ludlow rocks are very feebly represented in North Wales, especially so as compared with the lake county of Westmoreland to the north, where we have no less than 124 species, or southerly, in the true Ludlow area, where there are 390. Hitherto North Wales has only yielded 19 species; doubtless, could the continuity of the old sea bed and its deposits be examined between Denbighshire and Westmoreland (now under the St. George's Channel or denuded away), we should find the Denbighshire and Ludlow rocks and Ludlow species uniting the two now disunited areas.

Knowing how large a fauna the Wenlock beds overlying the Denbighshire grits near Llansannan possess (65 species), as well as the extensive series near Llangollen (Castel Dinas Bran and Fron Fawr, &c., with Fredd-y-Fedwin, Mynydd Tryfan, near Llansannar), it is not a little singular that we do not meet with better or more extensively developed Ludlow beds and fossils through North Wales, especially so with Shropshire on the south, possessing 180 species, and Westmoreland to the north, with 127, which corresponds closely with the Worcestershire and Herefordshire grouping, where about 120 species occur in each, and 67 in the so-called passage beds between the upper Ludlow and lower old red sandstone in the Ludlow promontory. The distribution for Ireland and Scotland is 32 and 63 species, but they do not here enter into correlation.

The following table will show the number of occurrences and the geographical distribution of the Ludlow fossils, or value of its fauna for those eight areas where best developed or understood, and includes every species known up to the present date:—

Areas.	Occurrences.
Shropshire	181
South Wales	163
Westmoreland	127
Herefordshire	114
Worcestershire	120
North Wales	19
Scotland	63
Ireland	32
	839

The number of known species is 387, not including the *Plantæ* (5 species), which appear in the above-mentioned areas in the proportions given, and speaks for itself as regards the paucity or wealth of species of any given area, and it must be remembered that the localities have been long and well-searched, and therefore probably near the truth. These 839 occurrences represent their distribution in space. It is equally important to observe the differences in the triple division of the Ludlow group, in which the middle or calcareous lenticular aymestry limestone contains only one-third of the species in the Upper Ludlow (or 83), as compared with the Lower Ludlow 222, which gives us for the three formations or horizons 565 appearances or their distribution in time.] R.E.

DESCRIPTION OF THE SPECIES.

Plantæ.

Rare as are all remains of true plants in Silurian rocks,* we yet cannot doubt that the more calcareous Algæ would leave their traces behind them; while the merely cellular mass which forms the frond of ordinary sea-weeds could leave at most but a carbonaceous stain. It is not improbable, indeed, that many of the black slates so frequent in Lower Silurian rocks owe their colour, at least in part, to decomposed Algæ. It is certain that these must have existed, if only as the food for marine animals. But we have scarcely any definite proof of their occurrence in British Silurian rocks, though so often quoted under the name of Fucoids—a term which ought really to be expunged from our lists.

Hydrozoa?

Oldhamia, Forbes, 1848.

The *Oldhamia* of the Cambrian rocks may possibly be a calcareous *coralline*, and some authorities refer it provisionally to plants, and not to the Hydrozoa. Mr. Busk rejected it from the Bryozoa. There is no good evidence that it belongs, as Prof. Forbes and Dr. Kinahan thought it did, to the *Sertulariadæ*, and the Rev. Mr. Berkeley suggested *Acetabularia* as its most likely ally.

The structure, though obscurely jointed, shows no trace of definite cells, such as the Hydroid Polypes, or the Bryozoa would present. But great latitude in this respect may be allowed for sea plants of the Nullipore group; and *Oldhamia* may be as one of these.

We do not doubt that the two species belong to different genera. Prof. Göppert in his Flora Silur. Dev. und Unter-Kohl divides them into *Oldhamia* and *Murchisonites*, comparing the *O. radiata* with the *Tirocoleum* of Cayenne, or more readily with the *Tolypothrix coactilis* of Jutland. He gives the characters of the genus thus,—abbreviated,

Oldhamia (*O. radiata*, Forbes).—Frond of tufted filaments, sessile, radiated, much branched. Branches [excentric?] close set, simple, dichotomous, or forked.

Murchisonites (*O. antiqua*, Forbes,) he defines as follows:—Frond with geniculate jointed flexuose stem, giving off at the angles secondary ramuli, united at their base into fan-shaped fronds, which are bifid, either from the base, middle, or apex, and compares it fairly enough with the living *Liagora ramellosa*, Kützing, a Teneriffe sea-weed.

These analogies seem all striking, and indicate close study. But, in truth, *Oldhamia* must have had a calcareous or semi-calcareous structure to have been preserved at all, and the comparison with the *Acetabulariæ* must not be disregarded. Prof. Göppert does not seem to have perceived that the hard filaments must needs have been connected by a membrane, now quite destroyed; and that the fronds must have been sufficiently hard to impress the sandy deposits in which they are imbedded.

Prof. Kinahan's important paper on *Oldhamia* in the Transactions of the Royal Irish Academy, p. 241, gives elaborate figures of the radiated species; but he failed to convince Mr. Salter of the presence of vesicles. The cells? being inflated, give a spurious appearance of such structure.

It is better to keep such obscure fossils in a single genus, as first described; and as the characters of the species are those given above for the genera, they need not be repeated.

We place these singular organisms provisionally in the class Hydrozoa, believing them to have close affinity with the *Sertulariadæ*, and belong to that

* Only 7 species known, and 5 of these are Upper Silurian, and illustrate 7 genera.

group rather than the calcareous *corallines*. Mr. Salter searched the Cambrian grits near Bangor for this genus, but without success.

O. radiata, Forbes.

Journ. Geol. Soc., Dublin, 1848.

Kinahan Trans. Roy. Irish Acad., vol. xxiii., p. 557, Pl. 26, figs. 4, 5; and variety, or new species, figs. 6, 7.

O. radiata, Göppert; Flora Silurisch. Devonisch. Unter-Kohl, Pl. 34, figs. 1, 2. For the synonyms and localities see Baily, Geol. Mag. 1865, vol. ii., p. 6, 395, f. 5.

O. antiqua, Forbes.

Journ. Geol. Soc., Dublin, 1848.

Kinahan Trans. Roy. Irish Acad., vol. xxiii., p. 557, Pl. 26, figs. 1–3.

For synonyms and localities, see Baily loc. cit. *Murchisonites antiquus*, Göppert, l. c. Pl. 35, fig. 1. *O. antiqua*, Baily, Geol. Mag. 1865, l. c. f. 3, 4.

These fossils are as yet known only in the Wicklow mountains, the *O. antiqua* being the more rare; *O. radiata* is found in plenty at Bray Head.

Protozoa.

Protozoa. Spongida.

Protospongia, Salter, 1864.

P. fenestrata, Salt. Quart. Journ. Geol. Soc., vol. xx., p. 238, t. 13, f. 12.

This is the earliest Protozoan known, and there can be no doubt about its being one of the Spongida. M'Coy's *Acanthospongia*, referred to by Salter, loc. cit., p. 238, appears to have possessed six rayed spiculæ; the spiculæ of *Protospongia fenestrata* are quadrate and appear to be all in one plane, but another form, also from the Menevian beds of St. David's, possess long acicular or needle shaped spiculæ, having no approach to the quadrate cruciform, or six-rayed character, resembling, indeed, terminal portions of Hyalonema without the sagittation or denticulation; neither is there any appearance of the connate or tuffed condition (bundles of spiculæ) which are apparent in some of the spicular portions of *P. fenestrata*. No sponges have yet been detected in the Menevian and Lingula flags of North Wales, at least so far as we know. 13 genera and 22 species are known in the Silurian rocks, and 1 genus and 1 species in the *Cambrian* of the Survey.

Formation and Locality.—Longmynd, Menevian, Lingula Flags, St. David's.

Protospongia? major, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401, t. 16, f. 14–18.

Formation and Locality.—Longmynd and Menevian Group, St. David's.

Protospongia? flabellata, Hicks. Quart. Journ. Geol. Soc. vol. xxvii., p. 401, t. 16, f. 19.

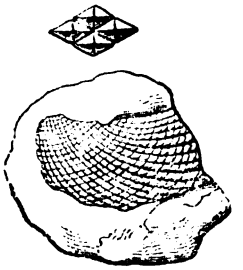
Formation and Locality.—Menevian Group, St. David's.

P. diffusa, Salt.—Menevian, St. David's. Brit. Assoc. Report 1865, p. 285.

Spongida (*Amorphozoa*).

Ischadites antiquus, Salter.

Fig. 4.



A mere fragment, and hence not very easily compared with more perfect species. Yet, as the rhomboid areolæ are very narrow, *i.e.*, the intersecting lines cross one another at an acute angle, the species may well be kept apart from the better known *I. Kœnigii* of the Ludlow and Wenlock strata. Moreover the longitudinal and transverse lines are very faint compared with the oblique ones. In the Upper Silurian species they are strong and deep.

It is not generally known that the genus occurs commonly in Lower Silurian rocks. A fine specimen, of a new and undescribed species, with strong projecting spines on the fibres of the areolæ, is found near Llangollen. And this specimen shows, what is seldom seen, the attaching root fibres, branched and divergent in the muddy matrix. Again, a fine *Ischadites* is found in the Caradoc limestones of Sweden.

Several species yet undescribed occur in the Woolhope and Wenlock shales of Malvern and Usk. In fact a mass of material has now accumulated for the illustration of the *Amorphozoa* of the Silurian rocks. We have some of the genera beautifully illustrated by Römer in his "Silurian Fauna of Tennessee" (*Astylospongia*), with others more regular in form, which appear to be widely diffused in Europe and Asia (*Sphærospongia*). And there are many others, some with calcareous spicula of enormous comparative size.

Formation and Locality.—LLANDEILO or ARENIG; Garn, Arenig Mountain, lying immediately on the traps.

Cœlenterata.

ACTINOZOA.

Monticulipora (*Nebulipora*) *favulosa*, Phill.

Mem. Geol. Surv., vol. ii., pt. 1., pl. 30., f. 3., (Llandeilo flags,) var. *β lens; Nebulipora lens*, M'Coy, Pal. Foss. Woodw. Mus. pl. 1 *c.* f. 7 (Caradoc strata).

The only figure engraved of this species is transferred to the Caradoc plate (t. 19, f. 10), believing the above varieties to be such, and not of specific value. The clusters of (fertile) cells are about the same size in both, but less regularly hexagonal in the only Landeilo specimen we have. The intermediate cells are smaller, when compared with specimens of the same size from Caradoc beds,—and also less regularly hexagonal.

These differences may be enough to constitute a distinct species, but probably they are mere varieties. The Caradoc form is at first simply lenticular, or rather plano-convex, but becomes with age highly convex, sometimes gibbous. It grows fully two inches wide.

Formation and Locality.—Common (the var. *β*) through the CARADOC or Bala beds in the districts of Shropshire and Wales. The original species came from near Llandeilo, S. Wales, in LLANDEILO BEDS.

Echinodermata.

Glyptocrinus? (*Cœlocrinus*, Salt. 1866 MS.) *basalis*, M'Coy.

Sagenocrinus, Austin, 1843.

Pl. 23, fig. 4; 4 *a. b.*, pelvis; 4 *d.*, rings of stem; 4 *c.*, arms and fingers.

G. basalis, M'Coy, Synopsis Woodw. Mus., pl. 1. D., fig. 4; Siluria, 2d. ed. Foss. 29, p. 206.

Better specimens than M'Coy possessed show clearly that this can hardly be referred to *Glyptocrinus*, inasmuch as it has subradial or parabasal plates, as in *Rhodocrinus*. Mr. Billings has given diagrams of a species of the latter genus, (Decade 4, Canadian Survey, pl. 1), which would fit generically with our fossil, but differs entirely in aspect and proportions. The genus *Thysanocrinus* (Hall, 1852) with which he considered his *Rhodocrini* identical (*see* his p. 27), may or may not be comparable with that genus. But *Thysanocrinus* is not safely identifiable with the present fossil, since it has but a small cup, with scarcely radiated plates, it may be a minute pelvis.

Mr. Salter proposed the name *Cœlocrinus* for this fine large fossil, at the same time did not adopt it owing to multiplying generic groups in an already over-burdened family.

At present we have no certain clue among the affinities of this complex group.

M'Coy's diagnosis, with additions; and the formula for the genus *Cœlocrinus*, if genus it be, would stand thus :—

Stem, simple, round, hollow, the canal very large.
Basal plates, 5, large and distinct.
Subradial plates, 5, hexagonal.
Radial plates, 3×5.
Inter-radials on all sides, numerous.
Interbrachials, many.
Arms, of a single row of bones, 10.

Hall does not give the number of arms for *Thysanocrinus*, nor do his figures show it. *Rhodocrinus* has 20, *Glyptocrinus* at least 20, ours has certainly only 10, with a double row of plates richly feathered with long tentacles.

The stems of this species are very long, quite cylindrical, of numerous close-set rings alternately larger and smaller, and hollow within so as to leave a large central cavity. The cup is semipyriform, about 1½ inches long, strongly marked by 5 great radiating ridges forked half way up; the pelvic plates wider than high, and much thickened internally, the subradial plates (pelvic, M'Coy) hexagonal, slightly longer than the primary radials, these are 3 in number, marked by a strong ridge which forks at 60° in the upper one. Three secondary radials are ridged in like manner; the ridges strongest towards the edge of the cup. The inter-radials and interbrachials are numerous.

There is a curious character in the pelvic plates, when viewed on the inner surface (not observable outside): each plate has a number, varying from three or four, to more than a dozen, of minute sharp tubercles, which are in pairs, the pair being divided by a slender ridge. These tubercles indicate, of course, an equal number of sharp indentations on the cast, which are arranged along the edges, or at the angles of the plates, or more commonly still on either side of the faint radiating ridges. In the cast they strikingly resemble the surface pores of the *Sphæronites*, with which they may possibly have more to do than appears likely at first sight. They do not mark true perforations in the plates.

All the plates seem to have been thin, and show considerable variety in form, from slight pressure. All are marked by thick radiating ridges, those on the radial plates being by far the strongest.

Professor M'Coy does not mention the arms, which (in Fig. *c*) are seen to be short and broad, very unequal in length, one arm at least being greatly longer than the rest;—the joints short, but apparently not in double rows, the plumes very long and made up of compressed joints. The number of arms is only 10, and they are unbranched.

The stem-rings are the most easily recognised portions of this fossil, which, in fragments, are most characteristic of the Caradoc series. Loose stem-rings, easily known by their wide central canal, are scattered over all the sandy slabs of slate near Bala Lake, on the Berwyn Mountains and elsewhere. The perfect pelvis is not uncommon, especially near Meifod in Montgomeryshire.

Formation and Locality.—CARADOC rocks.—Everywhere in Wales. Figs. 4, 4 *a*, Guilsfield, near Meifod; fig. 6, near Llanwddyn, in Berwyn Mountains; figs. 4 *c*., 4 *d*., Bala.

Dendrocrinus? Hall, 1852.

D. cambrensis, Hicks. Quart. Journ. Geol. Soc., vol. xxix., p. 51, t. 4, f. 17-20.

Formation and Locality.—TREMADOC. Ramsey Island and St. David's.

This is the oldest crinoid in the British rocks.

Cyathocrinus,—sp.

Pl. 11 B., Fig. 9.

A fragment, not half an inch long, composed of alternating joints, larger and smaller, and with a rounded outline. The section of the stem is pentagonal, or rather 5-parted, and very small central canal.

This is clearly distinct from *Glyptocrinus* in the Caradoc rocks. The very small canal and angular stem alone separates it. There are species of the genus *Cyathocrinus* with 5-angled stems, but the name must be considered rather as a family—than as a generic—one.

Formation and Locality.—ARENIG, W. of Stiper Stones, Shropshire.

CYSTIDEÆ, Von Buch.

Of all the species known of this curious tribe, none are so abundant as some of those which are figured in our plate 20. First recognised as British fossils by M'Coy, who described a large and common Irish species from Wexford; the British *Cystideæ* received scientific arrangement, and a full discussion, at the hands of Forbes, in his excellent essay in the Memoirs of the Geological Survey, vol. ii., pt. 2, pp. 483–538.

Von Buch and Volborth had previously described the Russian species, and established the main genera; and later than all, the clear synopsis by Joh. Müller, translated from the Berlin Transactions of 1853 by Huxley in 1854,* has rendered the arrangement and description of the *Cystideæ* an easier task than could previously have been supposed.

In truth the group, numerous as it is, and variable as the species are in form (and mode of preservation, an important item in the case), is very definite in character, and it is not difficult now to determine the genera, whatever may be thought of the claims of the several species.

Billings' discoveries in Canada have largely tended to illustrate the subject, and his work is admirable so far as it goes.† And the later volumes of Hall are full of good material.

The whole group is essentially in contrast with the contemporary but much longer-lived companion group, the *Crinoids*. With globular bodies, scarcely showing any oral surface, short inconspicuous stems, and for the most part rudimentary arms, which, indeed, seem to be sometimes absent altogether, or reduced to a few tentacles, the contradiction of character, in the *Cystideæ*, as compared with the long stems and plumose arms of the *Crinoids*, must strike even a casual observer. The rhombs and pores on the surface are hardly less remarkable characters, and in the form they assume peculiar to the group.

The pores are considered, whether concentrated in the peculiar rhombs, as in *Echinoencrinus;* covering the surface of all the calycine plates, with canals connecting them, as in *Echinosphærites;* or simply scattered in pairs over the surface, as *Sphæronites;* to be analagous to the respiratory pores of *Asterias*, and not to be passages in any sense for suctorial feet.

Müller's synopsis is as follows:—

I. *Cystideæ* with pore rhombs, *i.e.*, with the pores united by long canals, which extend from one plate to another, and are either—
   - *a.* Universal over the calyx, but covered over by external calcareous plates; the pores, therefore, only being visible at the ends of the canals: Ex. *Hemicosmites, Caryocystites.* (Upper and Lower Silurian.)
   - *b., c.* Universal, but connected from plate to plate by single or double canals, open on the surface, and visible, therefore, between the pores which they connect. In some species the canals are single (*b*), or even one canal serves for a row of pores; in others (*c*) two or even three or four canals are supplied to a single pair of pores. *Echinosphærites, Caryocystites* (which last genus seems to be only a subgenus of the former). (Lower Silurian.)
   - *d.* Pores and canals restricted to special portions of the surface, hence the species possess only a few pore rhombs. *Echinoencrinus, Pseudocrinites, Apiocystites,* and several other genera. (Upper and Lower Silurian.)

II. *Cystideæ* with double pores (*Diploporitidæ*); the connected pairs being on the same, not different plates. *Sphæronites, Protocrinites, Glyptosphærites.* (Lower Silurian.)

III. *Cystideæ* without pores. *Cryptocrinites.* (Lower Silurian.)

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* Annals and Mag. Nat. Hist., 2nd series, vol. xiii., p. 242. 1854.
† Canadian Organic Remains, Decade 3, 1858.

It is worthy of remark, that of all the genera, which are strictly Silurian, the only forms proper to the Lower Silurian are the two last, and those with universal pore-canals open over the surface. Of the others, those with covered pores are either Upper or Lower Silurian. And the genera with few pore rhombs occur also in both formations, but more especially in Upper Silurian. We have figured, pl. 20, the British forms given in Forbes' Memoir, reproducing the principal figures from his plates. And on the same plate have inserted the *Edrioaster* (*Agelacrinites*) *Buchianus*, Fig. 13., which he regarded as a *Cystidean*, but which Billings has shown to be nearly allied to the star-fishes.

We will reverse the order of these groups, and begin with the truly Lower Silurian forms. (No *Cryptocrinites* are known in Britain.)

Sphæronites, Hisinger, 1828.

Sphæronites pyriformis, Forbes.

Pl. 20., f. 1, 2.

Caryocystites pyriformis, Forbes, Mem. Geol. Surv., vol. ii., pt. 2., pl. 21., f. i.

The elongate, pouch-like form of this species easily distinguishes it from any other, and its pairs of pores are scattered evenly, but thinly, over the surface. The pores of each pair are also remote from each other, being separated by a prominent oval boss, encircled by a depressed line. When the surface is worn, this line becomes a raised border surrounding a slightly convex area. There is no furrow or depressed space to connect the pores, nor are they in any case sunk below the general surface, as in the two next species.

Formation and Locality.—CARADOC or Bala Limestone. Rhiwlas, Bala. Collected, as were all the other species in this locality, by Prof. Edward Forbes and Mr. R. Gibbs. (Mus. Pract. Geology.)

Sphæronites munitus, Forbes.

Caryocystites munitus, Forbes, l. c., pl. 21, f. 3.

A sub-globose, short, and rather minute species, not above half the size of the preceding, from which it further differs by the unevenly scattered pairs of pores. The pores of each pair are closer together, and set in oval depressions with a somewhat raised border.

Around the square mouth are four tubercles, which have their upper surfaces flattened, and may have borne arm joints. One of them especially is larger than the rest and more decidedly truncate. A thread-like ridge runs from one to the other of these bosses, and borders the mouth. The ovarian? aperture is very large. The six plates covering it, which Forbes has figured, cannot be seen, and therefore doubt them.

Formation and Locality.—CARADOC, Rhiwlas, Bala.

Sphæronites punctatus, Forbes.

Pl. 20., f. 7.

Sphæronites punctatus, Forbes, l. c., pl. 22, f. 2.

A large globular species, very common in the Bala limestone, but of which only enough is preserved to show the specific characters. It might possibly be a *Glyptosphærites*. The mouth was produced as in *S. pyriformis*, but the shape was much more globular, and apparently not attenuated at the base. The ovarian ?* (or anal) pyramid is very low and flat, and not divided visibly into any segments.

The pores are close set, very many on a plate, each pair linked together by a narrow and rather deep channel, with a slightly raised edge when the surface is perfect. When it is abraded, the pores alone show on the surface. Usually the straight short channels, huddled in irregular fashion over the plates, appear more like a rough sculpture than a structural arrangement. The pores appear, from one tolerable specimen, to be very rare near the base, and those of each pair are placed wider apart, with, of course, a longer channel connecting them.

* Salter believed Mr. E. Billings to be right; this is the anal, not the ovarian, pyramid.

Formation and Locality.—Caradoc, with the last, at Rhiwlas, Bala.
We also figure the following species from South Wales. They may all be found at Bala with a careful search.

Sphæronites Litchi, Forbes.

Pl. 20, f. 4. (3?)

Caryocystites Litchi, Forbes, l. c., pl. 21, f. 2.

There are two forms, and probably two species figured under this name in Forbes' paper, nor are the specimens quite good enough to show us the limits of the two species; our Fig. 3 is one of these, a species with large plates, and numerous, but not closely set, scattered pores, irregularly placed, and seated in small oval excavations, with a slightly raised border, on the surface of plates which, though tolerably even, are sculptured and granulated; Fig. 4 *c* also belongs to this species. It is common at Sholes Hook, Pembroke (*Caradoc*). But not being sufficiently figured here, Salter did not give it a name; indeed, felt little doubt but it was *S. munitus* in an older state. It has the oval tubercles and square mouth and scattered pores. Figs. 4, 4 *a*, 4 *b*, represent the true *S. Litchi*, in which the surface of the plates is thickly and evenly covered by areolæ, with raised thread-like borders separating them, and each bearing in its centre a ragged turbercle, which carries the pair of pores. It is the raised border of the pores highly exaggerated, and the reverse of the usual character in the genus, which has, on the whole, excavated channels for pores on an even surface. The pores of each pair are near together on the general surface of the body; but nearer the mouth and its curious tubercles, the pores begin to elongate and crowd each other into a sort of radiate structure. In some specimens near the mouth this structure is so much shown as easily to suggest to the naturalist a passage to those genera, *Echinosphærites*, in which the elongation of the channels and the elevation of their borders is normal and constant. *S. Litchi* may be looked on as a transition species. The resemblance to the tropical fruit *Litchi* is very close, but it required a botanist to see the analogy. Fig. 4 *b* is, as stated in the explanation of Forbes' plates, a magnified view of Fig. 4, and therefore it must be regarded in a reverse sense, the hollows being taken for elevations.

The curious epaulette-like tubercles which border the mouth are more developed in the *S. Litchi* than any other, and are deeply striated or ridged in a radiate direction from the mouth.

Locality.—Sholes Hook (Caradoc).

Sphæronites stelluliferus, Salter.

Pl. 20, fig. 6 (6 *a* wrongly figured).

S. aurantium? Forbes, Mem. Geol. Survey, vol. ii., pt. 2, Pl. 22, Figs. 1 *a*, *b*.

Forbes placed this species among the multiplied varieties of *E. aurantium*, for it really is allied to it; yet it differs in nearly all its characters. What was regarded (Forbes, *supra* Fig. 1 *a*) as the base is really the epauletted apex, and assuredly the external ornament (here figured 6 *a*) has been much exaggerated to suit the view taken of its affinities. It is far too much radiated; it is given in the hope of calling attention to the fact that the common northern species, *E. aurantium*, has never been found in Britain, unless the *Ech. granulatus* of M'Coy be, as Forbes suspected, the same species: it is very like it. *S. stelluliferus*, however, tends yet more closely than *S. Litchi* to unite the *Sphæronites* with the *Echinosphærites*. It has longer radii to the pairs of pores, and these are so arranged round the periphery of the plates, and extend usually so little into it, as to suggest the strongest analogy with the radiate surface-channels of *E. aurantium*. Moreover it occasionally happens, though rarely, that the linked pores are on opposite plates; while near the mouth of *Ech. aurantium* the two ends of the pore channels are sometimes on the same plate. Further observation will doubtless increase the points of transition, which in nowise tend to destroy the value of the genera.

A sub-globular and rather smooth species, with large polygonal plates, covered loosely with linked pores in narrow linear oval sunk channels, which vary in length from twice or less their diameter to five or six times that pro-

portion. They are not provided with raised borders, and are arranged radiately chiefly near the edge of the plates, but in part irregularly, the radiate pattern being sometimes obscure.

The mouth is oval?, not produced, its edge simply thick and incurved, and round it are arranged five (*not four*) of the epaulette-like tubercles above described in *S. Litchi*. Unfortunately the internal cast only was figured before ascertaining it was a new species. The surface of the cast is covered with numerous projections (very like Fig. 4 *c*), due to the numerous pairs of pores. As there are no traces of the pore-channels interiorly, there can, of course, be no radiate arrangement on the inner cast.

Fig. 6 *a* represents the outer surface, but, as above said, highly exaggerated as to the radiation. Nor is the central tubercle conspicuous; it is possible that Forbes allowed his artist to figure a portion of the true foreign *Aurantium* to make up for deficiencies in the British specimens supposed to be identical.

Formation and Locality.—Sholes Hook, CARADOC.

Echinosphærites, Wahl, 1821.

Echinosphærites arachnoideus, Forbes.

Pl. 20, fig. 8.

Sphæronites, Forbes, Mem. Geol. Survey, vol. ii., pt. 2, pl. 22, fig. 4.

This exquisite species is too well marked, and has been too fully described by Forbes, to need fresh illustration. The peculiar close striation is a good and striking character.

Formation and Locality.—CARADOC, Sholes Hook, Haverfordwest.

Echinosphærites Balthicus, Eichw.

Pl. 20., f. 10?

Sphæronites Balthicus, Forbes (also figured by Eichwald, Von Buch, Hisinger, &c.)

There is no doubt about this species, which is common in Pembrokeshire, but rare at Bala. It is quite distinct from the following, which, however, may be only a variety.

Formation and Locality.—CARADOC, S. Wales and N. Wales.

Echinosphærites Davisii, M'Coy.

Pl. 20., f. 9.

Caryocystites Davisii, Forbes, Mem. Geol. Survey, vol. ii., pt. 2, pl. 21., f. 5. *C. granatum*, id. (not Wahl.) f. 4.

In the simplicity of its ridges, this fossil differs from the *E. Balthicus*, with which Prof. M'Coy seems to think it cannot even be compared. Judging from Westmoreland specimens, however, it is likely to be, as Forbes suggested, closely allied to that fossil, if not a variety of it. The main ridges have frequently one on each side of them, the remaining space being flat, while *E. Balthicus* has ridge within ridge to the middle of the triangle.

The pore-channels are only faintly marked as radiations round the plates. But the concentric lines are strong enough in all the specimens.

The true *E. granatum* must be a very different species, judging from the figures. The two figured by Forbes will best agree with *E. Davisii*, M'Coy.

Formation and Locality.—CARADOC, Rhiwlas, Bala; Coniston, Westmoreland.

Hemicosmites, Von Buch, 1840.

Hemicosmites oblongus, Pander.

Pl. 20., f. 11.

Forbes, Mem. Geol. Survey, vol. ii., pt. 2., p. 511, pl. 20., f. 6. (*Echinosphærites oblongus* of Pander). Beitr, t. ii. (quoted as xi. by Forbes), f. 22, 23?

Forbes was right in referring to this figure by Pander, though he does so doubtfully. But the figure itself is so imperfect as to justify any amount of doubt, and by mistake the wrong plate is quoted.

Formation and Locality.—CARADOC slates of Sholes Hook, Haverfordwest.

Hemicosmites rugatus, Forbes.

Fl. 20., f. 12.

H. pyriformis, Von Buch? Forbes, l. c., vol. ii., pt. 2., p. 511., pl. 20, f. 2–5. *H. rugatus*, id. in vol. ii., pt. 1., p. 302. (*Echinosphærites malum*, Pander, Beitr. t. xxix. f. 1 *a*.)

It is unfortunate that Forbes did not retain his originally proposed name, *H. rugatus*, for there is little resemblance between Pander's smooth and only slightly ridged fossil, and this with strongly radiated plates.

Formation and Locality.—Caradoc, Sholes Hook, Pembrokeshire; Llanfyllin, Bala, N. Wales.

Pleurocystites, Billings, 1854.

Pleurocystites Rugeri, Salter.

Pl. 23, Fig. 5.

Fragments of this genus occur in the Bala limestone itself, and also in beds of the same age in South Wales. But these are so imperfect, that instead of figuring them Mr. Salter gives the outline of a perfect specimen from South Wales. It is only the internal cast, and shows the interior shape of the rhomb-bearing tubercles which ornament the surface, as well as the minute plates which cover one surface or side.

Our specimen shows a part only of one of the two long-jointed arms which are the characteristic mark of the genus; and for perfect figures reference should be made to Billings' beautiful plates in the Decade of the Canadian Survey iii., pls. 1, 2. Our species differs from *P. squamosus*, Billings (the species most like it), in the broad base, short form, and highly ornamented plates. *P. filitextus*, which appears from his description to come nearest in sculpture, has large plates on the lower (or irregularly plated) side.

The pectinated rhombs of this fine broadly-triangular species are very prominent, and flat or even convex above. The upper ones lie transversely, and are three times as long as broad. The lower rhomb is closer upon the cordate base of the cup than in any other species, so that the central area of the upper surface is conspicuously large. The basal plates project over the stem considerably. The upper plates are very thick, and their outer margin angular; the surface with the usual 6 strong radii reaching from centre to centre, with fainter intermediate rays branching from these; the interspaces filled with tubercles arranged in more or less of a concentric fashion. The lower or squamate surface is rather large, irregularly bounded by the marginal plates, and covered with minute, convex, granular scales.

Formation and Locality.—Caradoc, Blaen-y-cwm, near Llandovery S. Wales.

Protocystites, Salter, 1865.

Protocystites, Salter, 1865. Brit. Assoc. Reports, 1865, p. 285.

Protocystites menævensis, Hicks. Quart. Journ. Geol. Soc., vol. xxviii, p. 180, t. 5, f. 19; *ib.*, Camb. Cat., p. 3.

Mr. Salter gave a MS. name to some Cystidean remains in his "Report on further Researches in the Lingula Flags of S. Wales," Brit. Assoc. Report, 1865 (notes on the sections and fossils). Since then Mr. Hicks has named these fragments after the horizon in which they occur. These obscure fossils consist only of the arm ossicles and body plates, but being the earliest known Cystidean their notice here is important.

Formation and Locality.—Menevian, St. David's.

Asteriadæ.

Palæaster? Hall, 1851.

Palæaster obtusus, Forbes.

Pl. 23, fig. 1.

Mem. Geol. Survey, Decade I., pl. 1, fig. 3; Salter, Annals and Mag. Nat. Hist., 2d ser., vol. 20, described.

P. uncialis, depresso-convexus, branchiis obtusis subconicis brevibus [*insuper reticulato-spinosis*, Forbes]. *Ossicula adambulacralia maxima transversa, punctato-sculpta. Ambulacra angusta.*

The great breadth of the short arms is shown in Forbes' figure quoted above, but his specimen was not good enough to show the shape of the wide plates that border the narrow avenues, nor the deep punctated sculpture. The avenues are deep and narrow, the cavities for protrusion of the feet large and round. The avenues do not extend quite to the small mouth (and this is rare in starfish), towards which the adambulacral plates first become very narrow, and then appear actually to unite across the end of the ambulacrum. The upper surface is not known, but it was to all appearance not spinose.

Formation and Locality.—CARADOC or Bala ash-bed, west of Bala Lake; also Waterford, *see* Decade I., above quoted.

The *Asterias primæva* of Sedgwick's fossil lists may be this or the next species.

Palæaster asperrimus, Salter.

Pl. 23, fig. 2.

Annals and Mag. Nat. Hist., vol. xx., 2d ser., pl. 9, fig. 1.

P. triuncialis, convexissimus: brachiis fere cylindricis, obtusis. Pagina superior tuberculis 12-fariis plurimis exasperata, nec coronata. Ambulacra profunda, ossiculis magnis, acuticarinatis, angustis, transversis.

A larger species than the last; and with cylindrical blunt arms, having a very convex upper surface covered with close-set tubercles. Beneath, the avenues are deeply sunk, and the bordering rows of bones (adambulacral ossicles) wide, composed of transverse narrow bones, becoming narrower towards the small mouth; but apparently not united across as in the last species.

These transverse ossicles are very convex, sharp-edged, the ridge rising in some parts into tubercles. The small madreporic tubercle may be seen between the angles of the arms. The form of the species is not unlike that of *Asteriscus crassus*, Gray.

Formation and Locality.—CARADOC. A pretty species discovered in the Quakers' burying ground, near Welshpool. Two specimens have been found, and more should be sought for.

Palæaster imbricatus, Salter.

Pl. 23, fig. 8.

P. rigidus, uncialis. Radii breves conici, nec ad basin valde expansi, subcarinati, tuberculis seu jugis obliquis remotiusculis asperi.

Ray conical, its length about five lines, its breadth at base less than two lines. Only two rays are preserved; these are convex, slowly tapering, somewhat carinate above (we do not see the lower side), and ornamented by tubercles gathered into curved oblique rows, which run forward from the avenues toward the carina above, and are separated from each other by a space little more than their own breadth.

Formation and Locality.—CARADOC rocks, Llanfyllin, Montgomeryshire. The specimen is in the collection of Mr. Prosser.

Protaster, Forbes, 1829.

Protaster? (*Tæniaster*) *Salteri*, Forbes.

Pl. 23, fig. 3.

Ophiura, Quart. Geol. Journal, vol. i., 1845, p. 20; *Protaster?* Siluria, 2nd ed., p. 208; Annals Nat. Hist., l. c.

P.? disco nullo? brachiis lanceolato-acuminatis, apicibus attenuatis filiformibus, superne ossiculis latè concavis nec ornatis; ore parvo (vix petaloideo?).

This small species, long mislaid by the late Professor Forbes (after he had given it the above name), was recovered some years since, and is now in the Woodwardian Museum, Cambridge. It was found—a solitary specimen—in an old roadside quarry, among millions of *Orthides* and other common Lower Silurian shells.

The specimen shows nothing of the disk, and might therefore (if we could fully admit the genus *Tæniaster*) be placed in that obscure generic group described by Mr. Billings in 1858. If they are not *Protasters* that have lost their disk (*see* Siluria, p. 208), they must be admitted to form a distinct genus, and the name is a good one. The way in which the oral pentagon is formed is certainly different from that of *Protaster*. Only the large triangular terminal plates of the series which border the avenues enter into the composition of the mouth plates, while in *Protaster* proper an elegant series of ogives is formed by the addition of the modified plates of other parts of the structure (of the ambulacral plates certainly), and most probably of the disk plates; in other words, each ogive is formed certainly of four, and probably of six, plates. It may well be said, therefore, that *Tæniaster* has a simple character to distinguish it. But this only appears to be the case in *T. spinosus*. The *T. cylindricus* is much more like *Protaster;* and as our species differs somewhat from both, I prefer to leave it in the genus *Protaster* for the present, as a general designation for the Ophiuroid Silurian Starfishes.*

This little species, scarcely more than three-quarters of an inch broad from tip to tip, differs in its slender whip-like arms from all the other species of *Protaster* or *Tæniaster*. The arms are broader at first, a little fusiform, and then suddenly tapering to a long slender end,—composed of numerous segments, the transverse measure of which is full twice their length. The lateral plates are oblique, short, much overlapping the succeeding distal plate, and furnished with short spines. The basal plates are triangular, not very large, in pairs, not closely placed, nor bending toward each other. The arms above (we have only the internal impression) were marked by a narrow channel, the plates deeply concave over more than half their surface,—the edge nearest the mouth being thickened and curved.

Formation and Locality.—Caradoc Slate. Pen-y-gaer, Cerrig-y-Druidion; North Wales (specimen in the Woodwardian Museum).

Palæsterina, M'Coy, 1851.

P. Ramseyensis, Hicks, Quart. Journ. Geol. Soc., vol. xxix., p. 51, t. 4., f. 21–23.

The earliest form of starfish known in Britain. Found by Mr. Lightbody, of Ludlow, in the Tremadoc beds at the N. end of Ramsey Island.

Formation and Locality.—Tremadoc, Ramsey Island and St. David's.

Agelacrinites, Vanuxem, 1842.

Edrioaster, Billings, Canadian Decades, No. 4, 1858; *Cyclaster*, Billings, 1857, not of Cotteau, 1856.

Mr. Billings' beautiful illustrations of the genus, in the Canadian Decades, leave very little to be desired. But he has not definitely stated the grounds on which his new genus *Edrioaster* is founded.

Agelacrinites of Vanuxem† is supposed to be a decidedly sessile body, while the species described by Forbes as *A. Buchianus* is apparently not so; *Hemicystites* of Hall is also described as closely adhering to the shells of *Brachiopod.*

Still, as we do not know how far the less depressed form (*Edrioaster*) may have been attached, it is unsafe to alter names, except on better grounds than have been stated; we therefore prefer to retain the name *Agelacrinites* for all the Silurian species.

It had no stem, at least the jointed quadripartite stem figured by Forbes in his plate, and supposed by him to be connected with it, was never found in juxtaposition, and could not be a part of it. Moreover, Forbes does not make mention of the large buccal teeth, of which the marks are plainly evident, and which were first noticed in it by Prof. Wyville Thomson in our museum.

These teeth, which must represent the "lantern" in the *Echinus*, help to show the near union of the genus with *Echinocystites* of Thomson, an Upper Silurian form.

* They are true *Asteriadæ*, notwithstanding their form, so curiously illustrative of the Brittle stars. *See* Annals Nat. Hist. for 1861, vol. xx., 2d ser., pl. 9, f. 4, 5.

† Geol. Rep. N. York, p. 168.

According to Mr. Salter, both of these genera are sub-globular forms of *Asteriadæ*, an opinion which Prof. Thomson does not share, but which seems to be definitely supported, so far as the fossil we are describing is concerned, by Billings' authority: he would form a new group, the *Edrioasteridæ*, to include these Palæozoic forms. It would not be difficult to show in the group so constituted a relation to the *Echinidæ*, *Echinocystites*, and *Palæodiscus* are included in it.

A. Buchianus, Forbes.

Pl. 20, f. 13.

Mem. Geol. Survey, vol. ii., pt. 2, pl. 23, figs. 1, 2 (only).

The surface of the plates is granular, but no trace of spines; nor can there be seen the chain-like pairs of pores on the puckered membrane, as figured by Forbes in his fig. 7. The artist must have been deceived by the imbrication of the small calcareous plates which covered this surface.

The five indentations figured by Forbes, fig. 6, are clearly present, as stated by Wyville Thomson in his paper on *Echinocystites* (Edinb. New Phil. Jour., 1861, p. 8), and there is a great thickening of the oral ossicles, just within the mouth. All this is very confused in his figure, which, however, shows the anal pyramid of plates; and Forbes' fig. 8 shows (what he did not fully appreciate) the oval casts of the ambulacral pores, for the passage of the feet. Mr. Billings has recognised these in his transverse section of *Edrioaster*, and we have proof therefore that the so-called arms were ambulacra thickened interiorly. The ossicles had even the vaulted position common in recent starfish, and were, as in *Uraster*, thick and parallel, except where the suckers passed. As in all the Silurian starfish, these suckers were in a single row.

Formation and Locality.—Caradoc rocks at Yspytty Evan, N. Wales.

Annelida.

Cruziana, D'Orb., 1842.

Cruziana, D'Orbigny (Voyage dans l'Amerique Meridionale). (*Bilobites* in the plates.)

A group of large and remarkable fossils, doubtfully referred by its discoverers first to Articulata, and then (with less probability) to plants. The specimens consist of more or less elongated and convex impressions, deeply furrowed down the middle, sometimes quite bilobed, and from the median line the sides are plaited in an oblique direction, so as roughly to imitate leaf venation. They are of considerable geological interest, very similar forms occurring in the Silurian rocks of Spain,* Normandy, Britain, and North and South America. In Europe they are, as far as yet known, Lower Silurian; and are all of an elongated form, and occur in sandy strata. In the new continent they are of a shorter and rounded shape. Sir E. Logan has brought fine specimens from the calciferous sandstone of Canada, and in New York and the Western States the genus occurs under the form of *C.* (*Rysophycus* or *Fucoides*) *biloba*, Vanuxem, as high as the Clinton group or the upper part of the Middle Silurian. These broader forms have been ingeniously referred by Prof. Dawson to the burrows of crustacea (trilobites); but I think they cannot belong to them.

Cruziana semiplicata, Salter.

Pl. 3, figs. 1–3.

Salter, in Rep. Brit. Assoc., 1852, Trans. Sect. p. 5; Siluria, 2nd and 4th ed., p. 43, foss. 5, fig. 3.

Description.—Linear, several inches long without diminishing in breadth (extremities unknown), often an inch and a half broad, the central furrow strong or depressed, the sides convex and bent down below the level of the furrow. Plaits numerous and close, simple or branched, oblique, and reaching

* M. Prado, director of the Spanish Geological Survey, has sent us specimens from the Lower Silurian rocks of Almaden, and these are beautifully figured in his luxurious 4to work on the Province of Madrid, 1864.

from the furrow more than half way to the edge; the remainder of the sides is smooth. The plaits are generally simple, terminate abruptly at the smooth portion of the margin, and are nearly equal in length but of different thicknesses; occasionally they are branched from near their origin, and sometimes new ones are introduced as they proceed outwards. Occasionally they are fasiculated in twos and threes, and branched once or twice on their forward edge, the branches ceasing as they inosculate with the next plait. The specimen figured (fig. 6) shows pretty clearly that the frond has thickness, and was either a soft cylinder or a hollow one, the broken extremity showing the opposite face, and the cylinder having been filled with sand of a somewhat different colour to that beneath it.

The great planes or surfaces of arenaceous flag in which these fossils were found are considerably above the lowest layers of the Lingula beds. They occur near the Slate Quarries, Bangor, at the head of the short glacier-marked valley Cwm Graianog,* and form the great shelving precipices of the east face of Carnedd Ffiliast. From the mode in which the matted surfaces of *Cruziana* and the cylindrical bodies called *Chondrites* occur on the rippled-marked faces of the beds, it is most probable that the latter are the tubular contents of worm tubes, or rather the rejectamenta from their bodies as they passed through the silty layers. It is by no means certain that *Cruziana* too, though arranged by some among fucoids or sea-weeds, may not have been a worm tube or burrow filled up also; we adopt this opinion here.

Mr. Salter had the good fortune to find these specimens, and endeavoured in vain to ascertain whether the convex surfaces of the fossils were on the upper or lower sides of the beds: the specimens are abundant, and they in all probability occur on the upper surfaces; but only small portions of this particular bed could be observed *in situ*. Many of the precipitous faces are finely ripple-marked.

Formation and Locality.—"Lower Lingula Flags," Carnedd-y-Filiast, near the Penrhyn Slate Quarries, Bangor; Maentwrog, North Wales; also beneath the Stiper Stones, Shropshire (possibly this is only an allied species), Mus. P. Geology.

Annelide Burrows (*Chondrites, &c.*).

Pl. 3, fig. 4; pl. 4, fig. 13, &c.

Such remains as these, of an irregular cylindrical form, and from a line to an inch in diameter, are frequent enough in the sandy strata of the localities just mentioned. They often appear branched, but this appearance is almost always traceable to the crossing of the tubes over one another. They are nodose in parts, thickening and thinning again without any apparent regularity. Lastly, they are made up entirely of the sandy material of the stone itself; or, where any difference is observable, it is commonly the case that the substance of the worm-like bodies is of coarser and even purer sand than the matrix.

Chondrites acutangulus and *C. informis* (M'Coy) (Synopsis Pal. Foss. Woodw. Mus., pl. 1 A., figs. 4, 5) are clearly of like origin.

Mr. Salter believes that even the branched fucoids (where such are clearly branched and not merely formed by crossing tubes) must be referred to similar agency, but these peculiar forms do not require discussion here.

Formation and Localities.—In the Lingula Flags, almost everywhere; near Bangor, Maentwrog, Ffestiniog, &c., and in *all* the succeeding strata here described.

Scolites (*Annelide*, Burrows).

Pl. 12, fig. 2.

These are the ordinary fillings up of worm tracks in the sandy mud, which Mr. Salter distinguishes for convenience sake as *Scolites*, from the vertical double burrows, *Arenicolites*.

Formation and Locality.—Hard sandstones at the base of Arenig shales above Penmorfa, near Tremadoc (quarried). These are also common in all Lower Silurian rocks.

* Ramsay, Quart. Geol. Journ., vol., viii., p. 375.

Arenicolites, Salter, 1856.

Arenicolites (*linearis*, Hall?).

Pl. 11 B, fig. 27.

Scolithus linearis, Hall, Pal. N. York, vol. i., pl. 1, fig. 1.

Species cannot be distinguished among these burrows, except for some marked peculiarity in the form or arrangement of the burrow. Simply looped burrows of the same size, and in a very similar rock to that which in America is called the Potsdam Sandstone, were found plentifully by Salter, and afterwards by many observers, in the Stiper Stones, Shropshire. (*See* woodcut 2, p. 243, *supra*).

Formation and Locality.—ARENIG or UPPER TREMADOC? Stiper Stones, Shropshire.

Scolecoderma, Salter, 1866.

Mr. Salter proposed this term for all such membranous tubes (often much compressed) of annelides, found in palæozoic rocks, as are clearly not referable to the more calcareous, or at least semicalcareous, tubes of *Serpulites*. They are very common. In a few cases it is possible we may mistake impressions of sea-weed for these; but their position in the beds, often vertical or oblique to them, will determine that they do not belong to the Algæ; and the want of any branches or sub-division of the frond will also tend to determine them. Sometimes they are cylindrical, more often compressed, and we may distinguish this convenient but artificial genus, comprising probably many different genera of annelides, from the common *Scolites* by its having clearly possessed a wall or tube, which renders the cast easily separable from the matrix, while *Scolites* only represents the track of the burrow. Although Mr. Salter established the genus, he was doubtful about the first described species.

Scolecoderma? tuberculata, Salter.

Pl. 5, fig. 24.

Two inches and a quarter long, and one quarter of an inch broad, when compressed, and studded all along with a double row of tubercles (in pairs opposite to the segments?).

This is really all the description that can be given of the membranous fossil before us. It is a single cylindrical tube, not branched in any way, as a fuciod would be; and the tubercles are scarcely such as would be produced by patches of fructification. Still it has much the aspect of a seaweed, and many would be disposed to refer it to that class; still, for reasons above given, it is not likely to be a plant.

Formation and Locality.—LOWER LINGULA FLAGS. Pentre-felen quarry, near Wern gate, on the road from Portmadoc to Criccieth, Carnarvonshire.

Crustacea (Phyllopoda).

Hymenocaris, Salter, 1853.

Carapace ample, semioval, narrowed towards the front, curved downward at the sides, but not angularly bent along the dorsal line; no external eyes; antennæ?; abdomen as long or longer than the carapace, of nine transverse segments, the last with three pairs of unequal lanceolate appendages.

H. vermicauda, Salter.

Pl. 2, figs. 1–4; pl. 5, fig. 25 (abdomen; and pl. 1, tracks of do.).

Salter, Reports Brit. Assoc. Belfast, 1852 (p. 63).

H. bi-triuncialis, capite amplo, a latere viso trigono, plus quam dimidium corporis totius efficiente. Abdomen elongatum articulis 9, anticis paullulum latioribus, posticis angustioribus, ultimo (et penultimo ?) quadrato, reliquis transversis.

The characters of this crustacean (abundant in the upper portions of the true Lingula Flags) have been pretty fully given in the reports above quoted, but a few additional observations are necessary in explanation of the figures. Figs. 1, 2, 3, in pl. 2, represent the materials, such as they are, from which the

restored figure 4 is made out; and in one or other of these all the parts may be detected, though a good deal altered by pressure. In fig. 4 Salter omitted the three appendages to the head, for which fig. 3 appears to afford justification, because in no specimens subsequently obtained (and many have occurred since to Mr. Homfray, of Portmadoc) has any trace of these abnormal inarticulated appendages been found. Moreover, they have so suspicious a resemblance to the tail-spines, though not a trace exists of an abdomen crushed beneath the carapice in fig. 3, that it is hardly safe to trust to the mere accident of their position in a single specimen.

The carapace is convex, very thin, and shows a marginal furrow along the posterior border.

The nearly perfect abdomen (fig. 1), presented to us by Mr. J. E. Davis, shows the front segment narrower and smaller than the rest, and obliquely truncated on the sides. The abdominal joints appear to have been nine in number; they fit closely together, and their edges project very little, nor are they recurved (in this species) at the hinder and outer edges, but truncate. They must all have been convex like the carapace, from the appearances they present under pressure. They were probably, in the first five or six joints, four times as wide as long, and gradually increase in length and diminish in breadth backwards. The surface of the carapace and body segments is covered by short wavy lines.

The last segment bears a number of appendages, formerly supposed to be four or five in number; but the specimen figured in pl. 5 shows that there were six appendages—an outer short pair equal in length to the last segment, and then a smaller pair lying parallel and close together within these.

The tail-spines may have folded together, except when the animal required to expand them, as in many living crustacea; and when united, they might very probably form such an organ as could, when the creature swam near the bottom, have produced the indented marks on the slab figured in pl. 1. As such they have been described in detail in the Quart. Journ. Geol. Soc., vol. x., p. 210. When it was supposed there was one large spine, *see* fig. 4, as in *Ceratiocaris*, of course this explanation was easier still, but probably the two large spines lay close together. In all probability this is a Phyllopod crustacean allied to *Ceratiocaris*, from which it differed essentially by its entire (not bivalved) carapace, as in the recent *Nebalia*. The crust was very thin. The caudal appendages alone would separate it from any connexion with *Pterygotus* and its allies.

Formation and Localities.—Lower Lingula Flags, in fine sandstones (with *Lingulella Davisii*), Gwern-y-barcud (fig. 3); Moel-hafod-owen, and other places near Dolgelly; at Tremadoc, Ffestiniog, and at Point Seiont, Caernarvon, fragments apparently of this species occur.

Lingulocaris, M'Coy.

A thin bivalve crustacean shell, with a general form like that of a *Modiola* or *Mytilus*, with scarcely prominent beaks, and *no?* hinge teeth; the surface of the carapace is covered by fine raised concentric lines.

Lingulocaris lingulæcomes, Salter.

Pl. 10, figs. 1, 2.

Uncialis et ultra, tenuis, transversa, ovalis. Umbo vix prominens anterior, Margo anticus rotundus, posticus subtruncatus. Superficies lineis tenuissimis creberrimis perfecta.

A bivalved thin carapace, one inch and two lines wide, and only half an inch across the widest part, which is near to the posterior subtruncate end. The umbo very little elevated, but apparently convex; the anterior end rounded and short, the general surface gently and evenly raised, with, however, an indistinct obtuse siphonal ridge. The hinge margin is straight, shorter than the length of the shell, with no appearance of a hinge, but with an inflexed margin. The general shape is that of a *Modiola* or *Sanguinolites*, for which it was first taken. Professor Huxley suggested that it might be a bivalved crustacean.

The name *Lingulæcomes* was given, as a most appropriate one, by Professor M'Coy, to what he believed to be a *Lamellibranch* shell occurring with the *Lingula*. In reality, these where no more than specimens of the *Lingula* shell

pressed laterally, and so made to assume an unsymmetrical shape. As this, however, is truly a shell, either of some bivalve or crustacean, it is not unadvisable to use the specific name employed by M'Coy, and so recognise his diligent work among the old fossils.

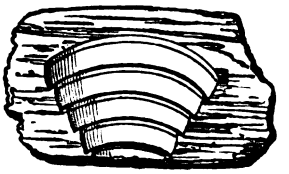
Formation and Locality.—UPPER TREMADOC, Garth. Mr. Ash's cabinet and Mus. P. Geology.

Ceratiocaris, M'Coy, 1850.

Ceratiocaris? latus, Salter.

Woodcut 5.

Fig. 5.



Four body segments (only) preserved. They are many times as wide as long, arched forwards, and taper backwards very rapidly, so that the fourth is only half the width of the first; the outer ends are strongly recurved, and produced into sharp points.

This differs so remarkably from *Hymemnocaris vermicauda* that we cannot doubt its being a different species, and very probably it belongs to the following species, provisionally referred to *Ceratiocaris*. It must have been very short and broad; and, therefore, whether it belongs to *Ceratiocaris* or not is impossible to decide without the carapace or latter body joints; the portions preserved are evidently the front rings only.

Formation and Locality.—UPPER TREMADOC, Garth, east of Portmadoc.

Ceratiocaris? insperatus, Salter.

Woodcut 6.

Fig. 6. Part of the last body-segment, *a.*; and the three tail-spines, *b. c. d.*; cabinet of Mr. Homfray.

This fossil may well belong to the same species as the preceding.

Tail-spines 3 [or 5 ?]; the central one lanceolate acute, at least an inch long, with a central ridge and marginal ridges; its base expanded. Side spines (*c. d.*) three-quarters of an inch long, about the same breadth, but with only marginal ridges (or it is possible there are two spines on each side, of which the outer is only half an inch long). This is hardly likely. Last body segment (*a.*) broad, with faint ridges.

It is difficult, from this single but precious fragment, to determine accurately whether the side spines *c. d.* be composed of two elements or not. Analogy leads us to expect a form in these rocks with fewer appendages than *Hymenocaris*, and more than *Ceratiocaris*, which is an Upper Silurian genus.

But on close examination of the side spines, nothing more seems necessary to explain the double markings than the impression of the marginal ridges of

two side *laminæ*. There are two, more or less distinctly seen, in all species of *Ceratiocaris*, and only two.

Formation and Locality.—Dark grey shales, passage from the LOWER TREMADOC to UPPER TREMADOC slate (near the iron beds), Penmorfa, Portmadoc.

Leperditiadæ.

Leperditia? cambrensis, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401, t. 15, f. 5–17.

Valves ¼ of an inch long, and $\frac{1}{6}$ of an inch in width. Common in the Red beds below the Plutonia and Purple Sandstones associated with *Lingulella primæva*.

Formation and Locality.—LONGMYND group, St. David's.

Leperditia Hicksii, Jones. Quart. Journ. Geol. Soc., vol. xxviii., p. 183, t. 5, f. 16.

The Cambrian and Lower Silurian rocks of St. David's contain this small species and a Primitia (*P. solvensis*), (*vide*), they do not seem to occur in North Wales.

Formation and Locality.—Horizon not definitely given. Another form (*L. vexata*) is mentioned by Mr. Hicks in his table of the distribution of the Cambrian rocks of the St. David's Promontory, South Wales. Prof. Rupert Jones believes this to be a Larval trilobite. (*Vide* Quart. Journ. Geol. Soc., loc. cit., p. 184.)

Primitia (*Leperditia*), Jones, 1865.

P. Solvensis, Jones. Quart. Journ. Geol. Soc., vol. xx., p. 238, 1864. Ann. Mag. Nat. Hist., 2nd Ser., vol. 17, p. 95, t. 7, f. 16.

Formation and Locality.—LINGULA FLAGS, Solva Harbour (west side).

Entomis, Jones, 1861.

Entomis buprestis, Salt., Hicks. Quart. Journ. Geol. Soc., vol. xxviii., p. 183, t. 5, f. 5. *Leperditia*, Brit. Assoc. Rept. 1865, trans. sect. p. 285. *L. punctatissima*, Salter; Siluria, Appendix, p. 519. 1865.

This species is from the Porth-y-rhaw section, St. David's.

Beyrichia complicata, Salter.

Pl. 19, fig. 9.

Mem. Geol. Surv., vol. 2, pt. 1, pl. 8, fig. 16. Pal. Foss. Woodw. Mus., Appendix, p. 136, t. 1 E., fig. 3. Jones in Ann. and Mag. Nat. Hist., 2nd ser., vol. 16, p. 163, pl. 6, fig. 1–5.

We merely reproduce the original figure of an extremely common fossil in Lower Silurian rocks. The genus *Beyrichia* has a range from the Llandeilo rocks,—to the Coal Measures. The species are usually characteristic of the several formations; *B. Klædeni*, perhaps, having the widest distribution, and *B. Wilckensiana* next.

Formation and Locality.—LLANDEILO rocks, S. Wales, CARADOC STRATA all over Wales, and also in Scotland.

Class CRUSTACEA.

Trilobita.

Rocks of the age of the Longmynds of St. David's have yielded new Trilobites under the research of Dr. Hicks. Since the publication of this Memoir and its Appendix, considerable addition has been made to the fauna of the Cambrian and Silurian rocks of St. David's and North Wales; this appendix would hardly be complete without reference to these new forms. It is not, however, essentially necessary to do more than notice them, as they do not come within the area under description.

Agnostidæ.

FAM.—*Agnostidæ*. The lowest and most rudimentary form of Trilobite. A single genus includes all we know of this group; and though departing, in

all technical respects, from the general characters of the Trilobite, there can be no doubt *Agnostus* is a true member of the order. Without eyes, without facial suture, with only two body rings, and with scarcely a distinction between the cephalic and caudal portions, it forms as it were the root or stipes from which all other varieties of the group take their rise. *Ampyx* is blind. *Trinucleus* has no facial suture. *Illænus* has the head and tail equal and similar. But these abnormal characters are all combined in *Agnostus*, which certainly *represents* in an adult state the embryonic forms of more perfect *Trilobites;* and it is one of the oldest known fossils, and associated with the great Paradoxides through the Menevian and Lingula flags, both of North and South Wales.

Agnostus, Brong., 1822.

Though greatly resembling in some respects the young stages of higher forms, *Agnostus* shows at once its mature character by the possession of a caudal shield, as well developed, and generally quite as large as, the head. The surface too is frequently ornamented, especially the border, and the lobes are well marked out both in the cephalic and caudal portions. The leading character of the Trilobite family—the facial suture—is altogether absent, and there are no eyes.

It is instructive to find this most rudimentary form associated with other and larger genera in which all the characters of the group are fully developed, in the same primordial zone. But it is to be noted, that either by excessive reduction, as in *Agnostus*, or excessive multiplication of segments, as in *Paradoxides*, the genera at this early period exhibit a defective organisation as compared with those of later formations. There is no sort of equality in organisation between an *Olenus* or *Agnostus*, and a *Phacops* or *Phillipsia*. Since the year 1866, six species have been added to this genus; all occur in the Menevian and Lingula flag groups at St. David's, South Wales; and three of the six occur in the same beds in North Wales. The species common to the two areas are *Agnostus Davidis*, Salter; *A. scutalis*, Salt; *A. Eskriggi*, Hicks; but *A. cambrensis*, Hicks; *A. scarabæoides*, Salt.; and *A. Barrandei*, Salter, have not yet been detected in any North Welsh locality. In all, 20 species are known, ranging from the Cambrian rocks to the Caradoc. Associated with the three species common to North and South Wales, we find *Arionellus longicephalus*, Hicks; and *Errinigs venulosa*, Salter; the former allied to a Primordial Bohemian species *Arionellus cetecephalus Barrande*, but larger, *E. venulosa* occurs both in the Menevian and Lower Lingula flags of St. David's and in the Waterfall valley near Maentwrog, North Wales.

Agnostus princeps, Salt.

Pl. 4, figs. 2, 11; pl. 5, fig. 1.

A. pisiformis, Salter, in Siluria, pp. 45, 53, foss. 4 and 9; compare with *A. exsculptus*, Angelin, Pal. Suec, t. 6, f. 8. Decades Geol. Survey, No. 11, pl. 1, fig. 1–5. Quart. Journ. Geol. Soc., vol. xx. p. 237, t. 13, f. 8.

A. latus, 7 lineas longus, scutis rotundato-quadratis, ad limbum rugoso-radiatis. Glabella subconica, tuberculo centrali antico; sulcis duobus transversis, lobis basalibus magnis instructa, sulcoque verticali ad marginem ducto. Annuli corporis bini, valde nodosi. Cauda axe magno rotundato, fere per totam caudam extenso. Margo edentulus.

More than half an inch long, with rounded-quadrate cephalie and pygideal shields, the limb of which is radiated with rough branched striæ. The glabella is three-fourths the length of the anterior shield, tapering and pointed in front, with a short anterior lobe, and a dividing ridge running from it to the narrow front margin. The axis of the tail is broad, full five-sixths the length of the shield, with two transverse furrows at its origin, and with a very large rounded terminal lobe; an elongated tubercle on the middle of the tail axis; a smaller one on the glabella. No marginal spines, not even on the tail.

The largest of all known species, except the Scandinavian forms, *A. reticulatus, A. aculeatus*, Angelin; from both of which it differs by the radiate, not reticulate limb. It is much more like a smaller species, *A. exsculptus*, ib.; but, if Angelin's figure be correct, the glabella, and tail too, differ widely.. The glabella is short and altogether simple, without terminal lobe or central tuber-

cle, and the tail axis is narrow, and a good deal like the glabella of our fossil. The general aspect is much the same.

Formation and Locality.—Upper Lingula Flags, Penmorfa Church, and Carreg-wen farm near Portmadoc, North Wales, 1860. Also in the shales of Whiteleaved Oak, &c., Malvern; (coll. by Mr. Strickland). *Tremadoc slate;* Portmadoc. Lingula Flags, Porth-y-rhaw, St. David's, Pembrokeshire?

[Appended is a description of the Swedish species; that it may be seen in what respects this long-known primordial species differs from others, and especially from the *A. M'Coyii* of the Llandeilo flags, under which name Mr. Salter designated the species common in the Llandeilo flags of Britain, and which was formerly published in the Silurian System as *A. pisiformis.*]

Agnostus pisiformis, Linn.

Syn.—*Entomostracites paradoxus* and *pisiformis,* Linn; Iter. Scan. 122; Syst. Naturæ, ed. 16, vol. iii., 160; *E. pisiformis,* Wahl; *Agnostus pisiformis,* Brongn. (1822), Crust. Foss. pl. 4, fig. 4; Angelin (1852), Pal. Suec., t. 6, fig. 7; *A. planicauda,* ib., t. 6, fig. 9, variety.

Spec. Char.—*A. elongatus, 5 lineas longus, valde trilobus, capite pygidioque ovali-truncatis, lævibus. Glabella longiconica, in duas partes, anticam trigonam parvam, posticam oblongam, divisa. Cauda axe magno longo lobato, apice obtuso; marginibus angustis brevidentatis.* Lingula Flags of Sweden.]

Comparing then the Swedish figure with that given in the Silurian System of the next described species, it will be seen that the general shape of *A. pisiformis* is much longer, and the glabella narrower and more pointed; its upper lobe instead of being larger than the lower is much smaller. There are also considerable differences in the caudal shield. It has a much longer axis than in *A. M'Coyii,* crossed by a very faint transverse furrow. As to the range of the two species, *A. M'Coyii* is as yet only known in the Llandeilo flags, and the true *A. pisiformis* in the Lingula group.

Agnostus Davidis, Salter.

Quart. Journ. Geol. Soc., vol. xxviii., p. 174, t. 5, f. 2–4; ib. Brit. Assoc. Report, 1865; ib. Cambridge, cat. p. 4.

This species occurs in the Menevian beds both of St. David's in South Wales and near Dolgelly, North Wales, and Rhaidr-ddu valley, Maentwrog, found in the latter place by D. Homfray, Esq.

Agnostus Eskriggi, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 175, t. 5, f. 7.

The Menevian rocks of St. David's and Dolgelly contain this species.

Agnostus cambrensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxvii., p. 400, t. 16, figs. 11, 12. 1871.

Formation and Locality.—Cambrian, Nun's Well, St. David's.

Agnostus scutalis, Salter.

Quart. Journ. Geol. Soc., vol. xxviii., p. 175, t. 5, f. 9–14.

An abundant species in both the Menevian areas, Maentwrog, in N. Wales, and St. David's, S. Wales.

Agnostus scarabæoides, Salter.

Quart. Journ. Geol. Soc., vol. xxxiii., p. 175, t. 5, f. 8.

Formation and Locality.—Menevian Group, St. David's.

Agnostus Barrandei, Salter.

Quart. Journ. Geol. Soc., vol. xxviii., p. 176, t. 5. f. 5, 6.

Formation and Locality.—Menevian Group, St. David's.

Agnostus reticulatus, Ang.

Pal. Scand., p. 8, t. 6, f. 10.

Formation and Locality.

Menevian, Tyn-y-groes, Mawddach River.

A. M'Coyii, Salter.

Pl. 13, fig. 8.

SP. CHAR.—*A. oblongus, depressus, capite pygidioque rotundatis, et ad thoracem contractis. Glabella oblonga, anticè vix incrassata, in duas partes subæquales, posticam circularem, anticam lunatam sulco divisa. Limbus undique æqualis, lineis impressis radiatis sæpe notatus, margini angusto. Cauda capiti simillima, sed axe clavato, lobo terminali majori semielliptico, mediano transverso brevi-tuberculato, lobis anticis prominulis. Margo distinctus, brevidentatus.*

SYN.—*A. pisiformis?* Murch. Sil. Syst., pl. 25, fig. 6 (fig. 4 in text), not of Brongniart; *Diplorrhina triplicata*, M'Coy (1851), Pal. Foss. Woodw. Mus., pl. 1 E., fig. 11 [not of Corda]; *Agn. M'Coyii*, Salter (1854), in Morris' Catal. Brit. Foss., 2nd ed.; Siluria, 2nd ed. pl. 3, figs. 7, 8; Id. Decades Geol. Survey, No. 11, pl. I., figs. 6, 7.

A frequent fossil in the black Llandeilo flags of Builth in Radnorshire, and the Arenig beds, Shelve in Shropshire, but as far as present known, not found elsewhere. It accompanies *Ogygia Buchii* and *Ampyx nudus*, and seems, like many others of its genus, to have delighted in a habitat of black carbonaceous mud, now converted into shale. It is fully described in Decade 11, and therefore only the diagnosis is given here.

Formation and Locality.—LLANDEILO FLAGS, S. Wales? Arenig of Shelve.

Agnostus trinodus, Salter.

Pl. 19, fig. 8.

A. brevis, semiuncialis. Caput suborbiculare, glabellâ convexâ, vix ⅔ capitis longâ, integrâ; limbo convexo. Cauda transversa, convexa; axe minuto conico, vix dimidium caudæ efficiente, utrinque bilobo, tuberculo magno. Limbus posticus convexus, à margine bispinoso et ab axe profundè sejunctus.

SYN.—*Trinodus agnostiformis*, M'Coy, Sil. Foss. Irel., pl. 4, fig. 3; in Pal. Foss. Woodw. Mus., t. 1 E., figs. 12, 13 (not fig. 11); *T. tardus*, ib., fig. 9. [*A. glabratus*, Angelin, Pal. Suec. t. 6, fig. 5]; *Agnostus trinodus*, Decades Geol. Surv., No. 11, pl. 1, f. 8. 10; *β, convexus*, Salter, in Mem. Geol. Surv., vol. ii., pt. 1, pl. 8, f. 12, 13.

The original figure in the Memoirs of the Survey was not quite satisfactory, for the tail segment (from decomposing limestone near Haverfordwest) had lost its axis-furrows and its marginal spines. It is replaced by better specimens in our Museum, from Ayrshire. The head has been found more abundantly than the pygidium, and is at once distinguished from all other British published forms (indeed from all except the kindred species *A. limbatus*) by the simplicity of its glabella, in which, and many other points, the species closely resembles *A. tardus*, Barrande.

Mr. Salter fully described this and other species in Decade 11 of the Survey Memoirs, and pointed out the differences between our species and the Bohemian one. M. Barrande when in England saw our species, but did not identify it with his own, nor are they to be identified.

There is no trace in Barrande's excellent figure of the slight lateral indentation in the glabella, which indicates the position of a furrow; nor of the lateral spines to the tail; they are also absent in the allied Swedish form *A. lentiformis*, Angelin. But the *A. glabratus* of Angelin, a Caradoc form from Besstorp in Vestrogothia, is far more like, and if we might suppose that the artist had made the form too elongate, and drawn the tail axis too large, we should consider it identical. The body rings in the Swedish species are very clearly shown (and ours should be sought for). The second ring differs a good deal from the anterior one.

These three species,—*A. tardus*, *A. glabratus*, and *A. trinodus*, would certainly make an excellent subgenus, distinguished by the absence of glabella furrows. But we do not wish, any more than M. Barrande, to cut up this most natural group, and therefore regard *Trinodus*, M'Coy, (*Arthrorhachis*, Corda,) as a section or subgenus only.

Mr. Salter wrongly referred in his first description of this species, quoting Professor M'Coy's synonym for the *A. limbatus*, next described, regarding both as varieties of the *A. trinodus*, and giving the present one the varietal name *β. convexus*. M'Coy corrected this error in the Cambridge work, where he again figured two imperfect heads of the species. These deficiencies have

been remedied by the excellent specimens figured in the Decade by Mr. Salter, and chiefly obtained by Professor Wyville Thomson from Ayrshire.

Formation and Localities. — CARADOC. — Haverfordwest in two or three places; Bala and other localities in North Wales; Chair of Kildare, Ireland; Penwhapple Burn, near Girvan, Ayrshire and Shineton, near Cressage, Shropshire.

A. limbatus (not here figured).

A. trinodus, Mem. Geol. Survey, vol. ii., pt. 1, pl. 8, fig. 11 (not figs. 12, 13, which belong to the true *A. trinodus*).

SP. CHAR.—*A. oblongus, depressus.* [*Caput orbiculare, glabellâ convexâ, brevi, integrâ, limbo depresso, anticè angustato, cum margine plano fere confluenti, nec sulco distincto circumscripto.*] *Cauda semicircularis, lata, depressa, axe elevato conico, basi ad thoracem articulatâ, latâ; lobis anticis triangulatis, a tuberculo mediano oblongo sejunctis; lobo terminali fere dimidium axis efficiente, apice acuto; limbo depresso subplano, cum margine confluente.*

The tail is all that can be relied on for the establishment of this species; for the head, although found at the same place and very probably belonging to it, is not so different from that of the last described species as to make it certain it belongs to this. Like the tail, however, this head has the broad flattened margin, scarcely distinguished by any definite furrow from the slightly convex limb. In addition to this character, the glabella, which resembles that of *A. trinodus* in shape, reaches further forwards than in that species, so that there is not so great a width in front of it as on the sides. The posterior edge is broken, but the lobes of the neck segment seem to be smaller and narrower.

The tail is three lines wide and two lines long; truncato-orbicular, depressed except on the axis which is elevated, and distinctly circumscribed, though not by an impressed furrow. It occupies less than half the length of the tail, and is of triangular conic shape, pointed at the apex, and broad at the base next the thorax. The anterior portion has a pair of lateral lobes, triangular, transverse, and rather convex, partly separated by the oblong median tubercle, which reaches from hence to the beginning of the terminal lobe, where it ends abruptly. The intermediate or middle pair of lobes are about as broad as the basal ones. The terminal lobe is large, occupying less than half the length of the axis, and is marked off by an obscure furrow.

The limb declines gently from the axis, without any separating furrow, and is of equal width at the sides and end. The margin is flat, not so broad as the limb, from which it is only separated by a shallow depression all round. There is an obscure trace of a lateral tooth high up on each side. The anterior edge of the tail is furnished with a distinct articulating portion (as in all the species when sufficiently perfect) and on the side-lobes the anterior edge is marked off by a deep groove.

With *A. trinodus*, the head supposed to belong to this species agrees very nearly, and only differs from it in the absence of the deep marginal groove, and in the less width of the limb in front. The tail has less resemblance, and in the great depression of all but the axis, and the conic or pointed form of that portion, differs entirely. The proportions of the axis, limb, and border also separate *A. limbatus* from either of the Swedish species *A. glabratus* and *A. lentiformis*. With no other can it be compared.

Professor M'Coy united the species with the *A. tardus*, Barrande; an identification which cannot be maintained, for that species is all but identical with *A. trinodus*.

Formation and Locality.—CARADOC.—Wexford (Survey coll.).

Agnostus, sp. (allied to *A. limbatus*).

Pl. 11 A, fig. 7, and woodcut 7.

Decades Geol. Survey, No. 11, pl. 1, fig. 12.

Fig. 7.

This is only the caudal shield of a species resembling the *A. nudus* of Beyrich (more like that species than any British one). The central portion is but faintly marked out, but is smaller in proportion to the limb than in the Bohemian species.

The length of the pygidium is less than two lines. It is long-semioval, the border concave, and is nearly as broad as the axis, which is half the length of the tail, not very strongly marked out, and has a small anterior tubercle.

The Caradoc or Llandeilo flag species *A. limbatus*, Salter, is somewhat like it in the broad and somewhat duplicated border, but differs in the much smaller axis, and more backward position of the central tubercle. Our species, imperfect as it is, is distinct from, and lies midway between, this species and the Bohemian *A. nudus*, a primordial form.

Formation and Locality.—ARENIG.—Tai-hirion, west of Bala, collected by Mr. Salter in 1853.

Fam. Olenidæ.

A large and ill-defined group, in some respects leaning towards the *Calymenidæ*, in others peculiar. The trilobites composing it are:—Long-bodied, with many free segments in the thorax, and very few (generally) in the post-abdomen. The *Olenidæ* are thus the very reverse of the *Agnostidæ*, which always bears them company. In geological time they are abundant in the Lowest Silurian Rocks up to the Caradoc group.

The family is not known to occur above the Caradoc, where the genus *Triarthrus* and *Cyphoniscus* show abnormal characters, and the group dies out.

Plutonia, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 399. 1871.

[The genus *Plutonia* was established by Mr. Hicks for portions of a large species found in the yellow flaggy sandstones of the Longmynd or Harlech group near Nun's Well, St. David's. These *Plutonia* sandstones are about 150 feet thick, and divide the two red series, or stand between the lower purple and greenish sandstones and the grey, red, and purple flaggy sandstones. *Plutonia* is allied to and has affinity with *Paradoxides* and the singular genus *Anopolenus*. *Plutonia* differs from *Paradoxides* and *Anopolenus* by having the whole carapace coarsely tuberculated or spined. In size *Plutonia* nearly equals *Paradoxides Davidis*, and is one of the largest species occurring in the Cambrian rocks. The number of body rings or thoracic segments are not known, neither are we acquainted with the nature of the *Pygidium*. *Conocoryphe*, *Microdiscus*, *Agnostus*, and *Paradoxides* are associated with *Plutonia* in the yellowish Cambrian sandstones at the headland near Nun's Well, St. David's.] R.E.

Plutonia Sedgwickii, Hicks.
Quart. Journ. Geol. Soc., vol. xxvii., p. 399, pl. 15, f. 1–8.

Formation and Locality.—CAMBRIAN.—Headland near Nun's Well, St. David's.

Paradoxides Hicksii (*Forchhammeri* on plate), Salter.

Brit. Assoc. Report, 1865, p. 285; *ib.*, Quart. Journ. Geol. Soc., vol. xxv., p. 55, t. 3, f. 1–10. Pl. 4, fig. 12.

P. Forchhammeri? Salter, Siluria, 2nd ed., 1859, p. 45, Foss. 5, f. 2; Decades Geol. Surv., No. 11, pl. 10, f. 9 (not of Angelin).

Our specimen must, when perfect, have been more than 3 inches long; although very incomplete, enough remains to show that the species is distinct from any of the Bohemian ones, unless it may be *P. Bohemicus*, and from either of the three Swedish species described by Angelin, except *P. Forchhammeri*, to which Mr. Salter formerly referred it.

But there are several points, according to Salter, in which it agrees with the latter species and differs from *P. Bohemicus*. The glabella is widely clavate, and the furrows across the base are parallel, or nearly so. The body rings, of which we have only 16 preserved, have the axis considerably narrower than the pleuræ, and the latter have only short points, and very oblique grooves. The second pleura is not elongated, nor at all wider than the third, another point in which it differs from *P. Bohemicus*, in which *P. Forchhammeri* does not offer means of comparison. But in the proportionate length to their width,

the pleuræ agree much better with the Swedish species, the length being rather more than three times the width; while in *P. Bohemicus* it is rather less.

Both in *P. spinosus* and *P. rotundatus* of Bohemia, and *P. Tessini* of Sweden, the two basal glabella furrows (besides the neck furrow) run strongly quite across. Our species therefore does not need comparison with them, as it has only one transverse groove above the neck furrow; the rest are very obscurely indicated in this specimen, which has been much compressed in an oblique direction.

Formation and Locality.—North Wales (exact locality uncertain, probably near Dolgelly).—(MENEVIAN or LOWER LINGULA FLAGS, for the same species, together with a very much larger form, the *P. Davidis*, has lately been described from the MENEVIAN beds of N. and S. Wales, and proves to be a new species.—J. W. S., 1865.)

Paradoxides aurora, Salter. Brit. Assoc. Report, 1865, p. 285; *ib.*, Quart. Journ. Geol. Soc., vol. xxv., p. 54, t. 2, f. 9–12.

This species, with *P. Harknessii*, Hicks, and *P. Hicksii*, Salter, are the earliest forms known of the larger *Olenidæ* (*Paradoxidæ*).

The grey *Plutonia* beds below or at the base of the Menevian group of Porth-y-rhaw contain these large forms of trilobites brought to light through the untiring energy and search of Dr. Hicks. *P. aurora* has not yet occurred in N. Wales.

Formation and Locality.—MENEVIAN GROUP.—Porth-y-rhaw, St. David's.

Paradoxides Harknessii, Hicks. Quart. Journ. Geol. Soc., 1871, vol. xxvii., p. 399, t. 15, f. 9–11.

Fragments only of this species have been found. Glabella large, having three complete furrows and two incomplete ones on either side. Eyes extending the whole length of the cheek, elevated at each extremity.

Formation and Locality.—CAMBRIAN.—Headland near Nun's Well, St. David's, and between Solva and Whitchurch.

Several species of *Olenus* are now added to the British list. The first originally described one, here again figured, is the—

Olenus, Dalmann, 1826.

Olenus micrurus, Salter.

Pl. 2, figs. 5, 6.

Decade II., Geol. Survey, pl. 9 (1849); Siluria, 2nd ed., p. 45, Foss. 4, fig. 2; Lyell's Elementary Manual, 6th ed., p. 573, fig. 663.

The above references will indicate where this now well-known species has been figured. It is not, however, by any means a common fossil, and it is necessary now to distinguish it from the following species, which appears to be the ordinary form in the lower black shales of North Wales. It is easily distinguished from *O. cataractes* by the incomplete and oblique lower glabella furrows, the shape of the small smooth subtruncate tail, and by the abrupt narrowing of the hinder body rings, which also have the fulcrum placed nearer than half way from the axis.

Formation and Localities.—LOWER LINGULA *Flags.*—Trawsfynydd; Dolgelly; Marchllynmawr; Portmadoc; all in N. Wales.

Olenus cataractes, Salter.

Pl. 5, fig. 23.

Nearly an inch and a half long, ovate, blunt at both ends, the head wide, nearly one inch broad; the body much narrower, tapering regularly to the tail.

The head is subtruncate; the glabella moderate in size, parabolic, not so broad as the cheeks, reaching forward nearly to the narrow frontal margin, and about the width of that margin distant from it, furnished with two pairs of furrows, of which the lower are complete across. The eye is nearly as far forward as the front of the glabella, and somewhat remote from it. The hinder angles of the head abrupt and short, scarcely reaching the fourth segment, the spines directed backward, not outward.

Body rings 15, their axis convex in all the segments, nearly as broad as the pleuræ, which regularly decrease in length from before backwards; they are obliquely pointed, with short spines directed outwards, but very little backward. The fulcrum of the pleuræ is placed beyond the half, even in the hinder rings. Tail short, semioval, with a very wide axis, of three rings, and the sides with two furrows.

This has for some time been known as a variety of *Olenus micrurus*. But closer examination shows many points of difference, the chief being that the axis is equally wide with the sides, and these last taper regularly, not abruptly as in *O. micrurus*. The tail is even more easily distinguishable, the width of the axis being greater than that of the sides; it has three rings, including the terminal portion; and there are two lateral furrows, not one only. *O. cataractes* has 15 body segments, *O. micrurus* 14. The head is much like that of *O. micrurus*, but the lower glabella furrows pass quite across. Compared with the Swedish *O. truncatus*, the greater breadth of the cheeks, and the longer more parabolic form of the glabella, will distinguish it.

Formation and Localities.—Lower Lingula Flags.—Maentwrog Waterfall, Merionethshire, in black shale strata full of *Agnostus pisiformis;* also at Treflys, east of Criccieth, Caernarvonshire, North Wales.

(*O. truncatus* is from Sweden, at Andrarum, in Scania, but is probably from higher beds than ours.)

Olenus scarabæoides, Wahl.

Pl. 5, figs. 2–5.

Wahlenb. Dalman's Palæadæ. Brongniart's Crustacès. *Peltura scarabæoides*, Milne Edwards's Crustaces. *Peltura scarab.*, Angelin, Palæont. Suecica, pl. XXV., fig. 8 (mala). *O. spinulosus*, Phill. Mem. Geol. Survey, vol. ii., pt. 1, pp. 55, 239?

O. scarabæoides, Murch., Siluria, 2nd ed., Appendix, Table, p. 540.

In size, as well as form, these pressed and distorted trilobites agree well with Christiania specimens presented by Dr. Th. Kjerulf. But ours show only 12 body rings, while Angelin figures 13. Then there are two rings to the axis of the tail, besides the terminal lobe. The marginal spines are not clearly seen, except in one example, fig. 5.

I agree with Mr. Salter and believe we may safely identify with this the small species found at Malvern, and described by Phillips under the name of *O. spinulosus?* It is certainly not Wahlenberg's species of that name.

Formation and Localities.—Upper Lingula Flags.—Carreg-wen, near Borth, and Penmorfa Church, both near Tremadoc, North Wales; White-leaved Oak, Malvern.

Olenus (*Parabolina*) *serratus*, Salter.

Pl. 5, fig. 6, 7.

Salter, Decades Geol. Surv., No. 11, pl. 8, f. 5, 1865.

(Glabella quite as wide in front as behind, with a broad neck-lobe, equal in breadth to the basal lobe. The upper lobe somewhat narrower. Fixed cheek broad, subtrigonal, equal to half the width of the glabella just below the eye.)

Tail, probably of the same species; semicircular, serrate, with short, somewhat radiating spines. Axis thick, of five prominent rings. Sides four-ribbed, the ribs duplicate and produced on the margin into short spines of less length than the limb, five on each side, the fifth pair of spines being set rather wide apart beneath the axis.

Mr. Salter much wished he could have identified this with the common *O. spinulosus*, Wahl., for the head is very like. But the caudal shield is decidedly different, and as it in all probability belongs to the same species as the head, but he felt bound to keep them distinct. The name applies to the tail only at present. The glabella moreover differs, as above described, from that of the true *O. spinulosus*, which tapers a little forward. In that species too the tail spines are greatly lengthened.

The section *Parabolina*, regarded as a genus by Angelin, was proposed by Salter in 1849 to distinguish the species of *Oleni* which have 12 body rings and a laciniate tail. *O. scarabæoides* might belong to this subgenus as so defined, but it clearly belongs to a different natural group, in which the cheeks are

much contracted and the glabella enlarged; in the majority of *Oleni* the very reverse is the case. Angelin has good reasons for supposing there are several distinct genera included under *Olenus*, but it is not easy to see the way to their definition yet.

Formation and Locality.—Upper Lingula Flags.—Carreg-wen, as above.

Olenus (*Sphærophthalmus*) *flagellifer*, Angelin?

Pl. 5, figs. 8, 9.

Sphæroph. flagellifer, Ang., Pal. Suecica, pl. 26, fig. 7.

The only difference observable between the Tremadoc specimens and the figure by Angelin, is that the glabella furrows pass quite across, while Angelin gives them as only lateral. But as this character of the complete transverse furrows seems to belong to the whole of the *Sphærophthalmi*, perhaps the artist has not sufficiently represented it. The other characters of the sub-genus are the short and wide transverse head, the cylindric glabella reaching the front margin.

Eurycaris, Angelin, again, has a broader front, and a wider and more parabolic glabella, thus leading from *Sphærophthalmus* to the true *Oleni*, of which *O. gibbosus* may be taken as the type. The characters seem from Salter's critical examination not to be absolute in any of these sub-genera, and hence they may all (and M. Barrande seems to be of the same opinion) be conveniently retained in *Olenus*.

Formation and Locality.—Upper Lingula Flags.—Carreg-wen, Borth. Portmadoc.

Olenus,—sp.

Pl. 5, figs. 10, 11.

A caudal shield only, triangular in shape, in the same slab with a head of the above or an allied species.

It has a narrower axis, with less distinct ribs than the tail of *O. gibbosus*, Wahl., and the limb is wider, and with only two duplicate ribs visible on its forward edge. *O. gibbosus* has several, and according to Angelin's figure the upper one runs out into a spine; but specimens in the Geol. Soc. collection do not show this spine, nor does Dalman's figure. Yet it is particularly noted by Angelin (whose descriptions are always clear, though far too short for easy recognition of a species) and is moreover in agreement with the general character of the genus. Possibly the two sexes differed in this particular.

Formation and Locality.—Upper Lingula Flags.—Carreg-wen, Borth, Portmadoc. Presented to the Mus. P. Geology by F. Ash, Esq., of Portmadoc.

Olenus (*Sphærophth.*) *alatus*, Bœck.

Pl. 4, fig. 3.

Olenus alatus, Bœck., Gœa. Norwegica, p. 143; *Sphærophthalmus alatus*, Angelin, Pal. Suec., pl. 26, fig. 9; [*Olenus bisulcatus*, Phill., Mem. Geol. Survey, vol. ii., pt. 1, p. 55, fig. 1, 2?]; Salter in Murchison's Siluria, 2nd ed., pp. 47, 538; in Decades Geol. Surv., No. 11, pl. 8, f. 6, 1865.

Our specimens are not very perfect, but there is no difference of importance between these and the figures by Angelin; and there are specimens in our museum of the Norwegian species, with the same characters. The great width of the cheeks in proportion to the glabella, and the strongly arched spines, are easily recognisable characters. The upper furrows are very obscure in our specimens.

Olenus bisulcatus, Ph., from the Malvern black shales, cannot be separated from this species.

Formation and Localities.—Upper Lingula Flags.—Carreg-wen, Borth, Portmadoc; Penmorfa Church, west of Tremadoc; White-leaved Oak, Malvern.

Olenus (*Sphærophth.*) *humilis*, Phill.

Pl. 5, fig. 12.

Memoirs Geological Survey, vol. ii., pt. 1, p. 55, figs. 4, 5, 6, 1848, Salter; Decades Geol. Surv., No. 11, pl. 8, f. 9, 11, 1865.

This is only here noticed to remark that this minute species is well characterised by the very *narrow* instead of *wide* cheeks. Yet, in other respects, it is a perfect *Sphærophthalmus*; and such a blending of characters indicates that

we are dealing with sub-genera rather than distinct and well-marked generic types. It is more fully described in our Decade 11.

Formation and Locality.—Upper Lingula Flags.—Black shales, Malvern, common.

Olenus impar, Salter.

Pl. 8, fig. 4.

O. uncialis, capite transverso semilunari, lato; corpore angustissimo. Axis thoracis latus convexus. Pleuræ breves falcatæ. Fulcrum ad axin appressum. Glabella marginem latum attingens, lobis duobus obscuris. Genæ quam glabella latæ, oculis parvis medianis, spinis prælongis, subparallelis.

A species with broader axis to the body, and smaller pleuræ than most others, except the *O. scarabæoides*. From this it differs materially in the great breadth of the head, and the long parallel head-spines, giving it the aspect of a small *Paradoxides*, under which name Mr. Ash sent it to Mr. Salter to figure.

The whole length is less than one inch, the head broad and rounded, transverse, about twice as wide as long, with a moderately long parabolic glabella, reaching the rather broad front margin; the cheeks in width about equal to the glabella, and having the eye midway and about half-way up the cheek, small, prominent; the head spines very long, nearly straight, parallel, and reaching as far as the extremity of the whole body. Glabella furrows oblique, not crossing the glabella, two on each side besides the strong neck furrow.

Only eight body rings can be determined, but there may be five or six more, for we have not the entire body. The axis is convex, much broader than the pleuræ in front, at about the seventh or eighth ring equal to them, and thence the pleuræ increase in proportional length. These are falcate, the tip considerably curved, the fulcrum very close to the axis in all the rings, just as in *Remopleurides*, to which genus our fossil bears a close resemblance.

It may be compared with *Olenus scarabæoides*, as to its body rings, but even that species has them not nearly so short proportionally; the head is however unlike.

Formation and Locality.—Upper Tremadoc Slate. Penclogwyn, near Portmadoc, Mr. Ash's cabinet.

Anopolenus, Salter, 1864.

Quart. Journ. Geol. Soc., vol. xx., 1864, p. 236.

Salter established this genus in 1864 * for the reception of a remarkable form closely allied to *Paradoxides*, differing chiefly in the position of the posterior cornu and greatly developed lateral spinous pleuræ of the pygidium, and with shorter and broader axis to the tail. In *A. Henrici* the grooves pass quite across the glabella, as in *Paradoxides*, whereas in *A. Salteri* the 5 depressions on either side do not pass across, and the number of thoracic somites are not more than 10.†

Three species are known, *A. Henrici*, Salter, *A. Salteri*, Hicks, and *A. impar*. All three species are from the Menevian and Lingula flags of St. David's. *A. impar* is also from the Menevian beds at Maentwrog, thus connecting the two areas by additional species.

Anopolenus Henrici, Salter.

Quart. Journ. Geol. Soc., vol. xx., p. 236, t. 13. f. 4, 5.

Formation.—Menevian and Lingula Flags.—St. David's.

Anopolenus impar, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 179, t. 7, f. 1–7.

This species differs essentially from its associated species, *A. Salteri*, which occurs *only* at St. David's, whereas *A. impar* is both a South and North Wales Menevian species; the third form, *A. Henrici*, is St. David's only; *Anopolenus* is essentially a Lingula flag and Menevian genus.

Formation and Locality.—Menevian Group.—St. David's and Maentwrog, North Wales.

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* Quart. Journ. Geol. Soc., vol. xx., p. 236. 1864.

† For character and differences between these two species, *see* Dr. Hicks, Quart. Journ. Geol. Soc., vol. xxi., pp. 477–482. 1864.

Anopolenus Salteri, Hicks.

Quart. Journ. Geol. Soc., vol. xxi., p. 478; *ib.* vol. xxviii., p. 179, t. 7, f. 8–11.

Formation and Locality.—MENEVIAN.—St. David's.

Carausia, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 177. 1872.

This genus is at present confined to the Menevian group at Porth-y-rhaw, St. David's. One species only is known, *C. Menevensis*. This genus was established by Mr. Hicks in 1872 to receive a nearly perfect specimen found at Porth-y-rhaw. Whether one of the *Olenidæ* it is difficult to say; the cephalic spines, pleuræ, and strongly-raised axis tend to place it in that family, none of the *Conocephalidæ* having had angles, and the pleuræ are mostly rounded.

Formation and Locality.—MENEVIAN.—Porth-y-rhaw.

Carausia Menevensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 178.

Formation and Locality.—MENEVIAN GROUP.—Porth-y-rhaw, St. David's.

Holocephalina inflata, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 178.

Formation and Locality.—MENEVIAN GROUP.—St. David's.

Conocephalidæ.

Dikelocephalus, D. Owen, 1852.

Centropleura, Angelin, 1852.

This genus, as defined by Dale Owen's figures, approaches very closely to *Olenus*, having the complete transverse furrows to the glabella; and, in some of them at least, the eyes, though not remote from the glabella, are connected with it by means of an ocular ridge. The pygidium, judging by his figures, is truncate behind, but not always produced into spinous angles. And it has a shortened many-ringed axis with numerous radiating furrows on the tail. Mr. Salter takes *D. minnesotensis*, *D. meniskatensis*, and *D. Pepinensis* as types.*

With these external characters, it is hardly right even to join our species *D. celticus* to the genus, as Mr. Billings in his excellent paper on the Quebec trilobites† has done with the *D. magnificus*. The glabella is quite different. But Mr. Salter only agreed with him with this and the other species, being unwilling to add to generic names, where the materials are insufficient. Such species as his *D. planifrons* (l. c., p. 309, fig. 6) and our *D. discoidalis*, pl. 5, fig. 19, are clearly more related to *Ogygia*, an affinity which was perceived by Mr. Billings.

Dikelocephalus (*Centropleura ?*) *furca*, Salter.

Pl. 6, fig. 4; and pl. 8, fig. 10. (fig. 9?)

D. [*capite transverso, margine frontali lato, glabellâ longâ, obscure sulcatâ.*] *Cauda subpentagona* (*sesquiuncialis*) *semiradiata, margine lævi quam axe latiori, margine antico obliquo, postico truncato, spinisque duobus latis brevibus approximatis.*

Pygidium an inch and a half wide, and, including the spines, one inch long, of a rough rhomboidal shape, rounded on the anterior edges, which retreat rapidly from the axis towards the widest part, and thence the tail contracts towards the hinder angles. These are produced into short blunt spines, and between them the hinder edge is straight and truncate.

The axis is long, conical, more than one-fourth the entire width (in *D. celticus* it is less than one-fifth), reaches nearly three-fourths down the tail, and is marked by six rings besides the rather blunt terminal piece (there is no appendix as in *D. celticus*). The sides are grooved by at least five principal furrows, faint where they join the axis, then stronger just before they bend down obliquely backwards, to follow the outline of the front edge. They do not nearly reach the margin, but leave a broad plain band, a quarter of an inch

* *D. granulosus* is a true *Olenus*.

† Canadian Nat. and Geologist, vol. v., p. 307.

broad. The incurved under portion (*caudal fascia*) is broader than this band, extending more than half way up the ribs; it is rather finely striate.

Compared with *D. celticus* (pl. 5, figs. 21, 22) our Upper Tremadoc species has the tail more pentagonal, the axis much broader and without an appendix, and moreover it has fewer axal and lateral ribs, the latter reaching not nearly so far toward the edge. The posterior margin is abruptly truncate (not rounded and emarginate), and the two blunt spines effectually distinguish the species.

The approximate tail-spines, and the faint half-developed lateral furrows, will distinguish it from *D. Minnesotensis*, Dale Owen. The *Centropleura dicræura* of Angelin, from the beds of his region B. C. (which answers well to our Tremadoc Slate), is by far the nearest species to ours. But it differs in the much closer tail-spines, and the elongated continuous lateral furrows.

Formation and Locality.—Upper Tremadoc. Moel-y-gest; and a variety? with stronger lateral furrows occurs at Penmorfa. Both are in Mr. Ash's cabinet.

Pl. 8, fig. 9.

The head, which we figure from Mr. Ash's specimen, most probably belongs to the same species as the tail described above. It differs from *D. celticus* in the longer glabella, which all but reaches the marginal furrow in front, and in the greater breadth of the margin itself. The eyes are placed further back. The glabella lobes are not distinct.

Locality.—Same as above.

Dikelocephalus? (Centropleura?) celticus, Salter.

Pl. 5, figs. 21, 22.

Caudal shield entire, $\frac{3}{4}$ inch long, $1\frac{1}{8}$ inch broad; rotundato quadrate, the posterior and anterior angles being rounded off, abruptly truncate and emarginate behind, and with no serrations whatever. The axis is narrow, prominent, gently tapering for nearly two-thirds the length of the shield, then abruptly attenuated into a narrow appendix as far as the margin. It is seven-ringed before its abrupt contraction, thence smooth. The sides have seven curved ribs, including the conspicuous front (marginal) one. These ribs are directed first outwards, then bent abruptly backward at the first fourth of their length, and so running obliquely to the margin; the second and third are duplicated. The posterior notch to which the appendix of the axis runs, is but shallow, but quite distinct.

There is a great general resemblance to the species so well figured by Billings in the Canadian Naturalist and Geologist, vol. v., p. 307. The axis of ours is however longer, almost double the proportionate length, the ribs more numerous, and the margin entire. It is still more like Angelin's *Centropleura? dicræura*, pl. 41, fig. 9.

Mr. Salter believed that a new genus should be constituted for these species; meantime, they are primordial fossils in this country, [Upper Lingula flag and Tremadoc slate;] while in America they probably help to fix the horizon of the celebrated calcareous beds of Quebec.* As these breccias and the intercalated shales must, from the *Graptolites* they contain, be older than the Llandeilo Flags, so it is probable that their lower beds should contain fossil genera of primordial date, mixed with others of later age.

Formation and Locality.—Upper Lingula Flag, or Tremadoc, ~~Ogof-ddu~~, east of Criccieth, in black slate.

Dikelocephalus? (Centropleura)? discoidalis, Salter.

Pl. 5, figs. 18, 19.

The glabella is a little narrowed in front, but then clavate, so as to give a somewhat urceolate shape. It is marked clearly by four short furrows, of which the second from the base is oblique from above inwards, and longest; the third is direct and short; the uppermost (fourth) very short and oblique from above outwards, towards the eye.

* There has been much discussion as to the true position of the Quebec beds. Sir W. Logan and Mr. Billings have now fully (Canad. Reports, and Geology of Canada, 1863) cleared up the whole relations of these limestones, which seem to occupy the place of the Tremadoc rocks in Britain, while the shales which lie above as clearly represent our Lower Llandeilo.

We have not the free cheek in its place; it is however greatly expanded and flattened, the eye is strongly lunate, smooth.

Of this, fragments only were obtained, but in considerable quantity; doubtless perfect specimens might be found. The front of the head is greatly expanded and flattened (without any marginal furrow) like the free cheeks. Our fossil agrees in all respects with the figure of *Dikelocephalus? planifrons*, Billings, except that the glabella is shorter. It is sufficient for our purpose that the type is exactly the same. It is very like *Ogygia* in the number and arrangement of the glabella furrows, and, according to Mr. Billings, in the labrum also it is like that genus.

Locality.—Ogof-ddu, Criccieth. UPPER LINGULA FLAGS.

Dikelocephalus? (Centropleura?), sp.

Pl. 5, fig. 20.

Caudal shield semicircular, the forward edge much curved, the axis narrow, tapering, convex, four-fifths the whole length of the tail, with eight distinct narrow rings, abruptly conical at the apex, then lost in the broad margin; sides with six curved ribs, the principal ones duplicate. This form much resembles the caudal shields figured of that genus on p. 311 of Mr. Billings' memoir, but not named. Loc. cit.

Formation and Locality.—Ogof-ddu, as above.

CONOCEPHALIDÆ.

If the *Olenidæ* are an ill-defined group, it is only because it is difficult to see the exact point at which they become distinct from this, which often accompanies them and ranges with them in time.

The *Conocephalidæ* may be assumed at present to embrace such genera as *Conocephalus, Solenopleura, Elyx* (and doubtfully *Ellipsocephalus* and *Arionellus*), together with *Sao*, which is a typical member of the group, and shows its close affinity with the *Calymenidæ*, and also *Angelina*, which has the facetted pleuræ and general character of this group, but might be equally well referred to the *Olenidæ* by its habit.

Conocoryphe, Corda.* 1847.

(*Conocephalus*, Barr.) 1852.

If this genus is to include such extreme forms as (*Harpides?*) *rugosus* of Angelin, or *Conocephalus Emmerichii*, Barr., as a middle term, and *C.* (*Ctenocephalus*) *coronatus*, Barr., at the other side, it is evident that we are allowing a wider range of variation than is usual in trilobite genera. It is more probably a small family group, and will hereafter be broken up, but we are not in a position to do this successfully as yet. It is safer to regard the principal variations as subgenera, and in this view, the two species here described will fall under quite distinct groups. For the characters of the genus see Barrande's Monograph.

His *C. Emmerichii* and *C. invita* will form one group or section, distinguished by the great size of the approximate eyes, comparatively large and well distinctly lobed glabella, 14 body rings, and small caudal shield, and might be called *Conocoryphe* proper.

Solenopleura, Angelin, is quite a distinct subgenus, with short scarcely lobed glabella, small, remote eyes, few (11 or 12) body rings, and a moderately sized caudal shield.

Conocoryphe coronata, Barrande.

Syst. Sil. Bohmeia, p. , t. 13, f. 20.

Conocephalites, Hicks. Quart. Journ. Geol. Soc., vol. xxviii., p. 178.

This Bohemian form was discovered by Mr. Homfray in the Menevian beds of the Waterfall Valley near Maentwrog. Barrande's figure (No. 20) shows no posterior spines to the cephalic shield. The specimen figured by Mr. Hicks possesses these appendages.

Formation and Locality.—MENEVIAN. Waterfall Valley, Maentwrog.

* M. Corda's name is used (Prodr. Monog. Bohm. Tril., 1847) on account of Zenker having previously employed the name *Conocephalus* as a genus of insects. But I adopt M. Barrande's view of the generic characters.

Conocoryphe applanata, Hicks.

Quart. Journ. Geol. Soc., vol. xxv., p. 53, t. 2, f. 1, 2, 4, 5.

This species occurs both at Porth-y-rhaw, St. David's, South Wales, and near Maentwrog and Dolgelly, North Wales. Juvenile forms of this species have been obtained, illustrating the metamorphoses of some of the Bohemian primordial forms, long ago pointed out by Barrande.

Formation and Locality.—Menevian Group. Porth-y-rhaw, St. David's, and near Maentwrog and Dolgelly, North Wales.

Conocoryphe humerosa, Salter.

Brit. Assoc. Report, 1865, p. 285; Quart. Journ. Geol. Soc., vol. xxv., p. 54, t. 2, f. 7.

Formation and Locality.—Menevian Group. Porth-y-rhaw, St. David's.

Conocoryphe Bufo, Hicks.

Brit. Assoc. Report, 1865, p. 285; Quart. Journ. Geol. Soc., vol. xxv., p. 52, t. 2, f. 8.

Formation and Locality.—Menevian. Porth-y-rhaw, St. David's.

Conocoryphe Solvensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxvii., p. 400, t. 16, f. 8.

Mr. Hicks found only a few fragments of this species: a perfect head and a few thoracic segments.

Formation and Locality.—Cambrian. Roadside between Solva and Whitchurch, St. David's.

Conocoryphe? variolaris, Salter.

Quart. Journ. Geol. Soc., vol. xx., p. 236, t. 13, f. 6, 7.

Formation and Locality.—Lingula Flags, Porth-y-rhaw.

Conocoryphe invita, Salter.

Pl. 4, figs. 5, 6, 7; pl. 7, fig. 7.

Decades Geol. Surv., No. 11, pl. 7, fig. 6.

C. capite (solùm adhuc cognoto) latimarginato, angulis brevispinosis, glabellâ urceolatâ, utrinque bisulcatâ: oculis longis, ad glabellam appressis; caudâ angustâ, axe conico 4-annulato.

We have portions only of the head, and the tail. The facial sutures converge greatly from the margin to reach the eye, which is very long, reaching two-thirds the whole length of the glabella. The glabella furrows nearly meet in its middle region, and both pairs are very oblique, the basal pair almost meeting the neck furrow.

This species so nearly resembles *C. Emmerichii*, Barrande, that, were it not for the glabella having only two pairs of furrows, it might readily be mistaken for that species. The glabella is longer, of an urceolate shape, and with the furrows reaching much further into it. The eyes are not quite so long, and are set close to the glabella, which is not the case in the Bohemian species. The tail is longer and narrower.

C. invita, with these points of difference from the Bohemian species, is nevertheless an excellent British representative of it. The next described species belongs to the same section of the genus.

Formation and Locality.—Upper Lingula Flags. Penmorfa Church, Tremadoc, North Wales.

Conocoryphe Homfrayi, Salter. Quart. Journ. Geol. Soc., vol. xxviii., p. 178, t. 6, f. 12. 1872.

Twenty species of the genus are known, none passing above the Tremadoc; it is therefore essentially a Cambrian and Lower Silurian genus.

Three species, *C. solvensis*, Hicks, *C. Lyellii*, Hicks, and *C. Bufo*, occur in the Longmynd rocks of St. David's. Seven are known in the Menevian of both areas, and 8 of these in the Upper Lingula flags, 5 in the Tremadoc, 3 being peculiar to that formation.

Formation.—Menevian. Waterfall Valley, Maentwrog.

Conocoryphe abdita, Salter.

Pl. 5, fig. 13.

Head three-fourths of an inch long, very broadly margined in front, with a crenulate marginal furrow. Glabella more than half the length of the head, with three lateral furrows, the lowest very oblique, separating a narrow triangular lobe, the upper furrows short.

This is figured as being clearly a distinct species from the *C. invita*, though closely allied. It has a very broad front beyond the glabella, the marginal furrow of which is crenulated as in *C. invita*, but the space in front of the glabella is twice the size. It has long eyes, as in that species, reaching from the upper furrow to the base, but remote from the glabella, not close to it. The facial suture takes a wide curve outwards beneath the eye.

Mr. Salter could not detect any species like it in Angelin's figures, unless some of his supposed species of *Proetus*, Plate XVIII., may possibly be allies, but to Barrande's *C. Emmerichii* both this and the preceding species have the closest affinity.

Formation and Locality.—Upper Lingula Flags. Ogof-ddu, near Criccieth, in black pyritous slate.

Conocoryphe Lyellii, Hicks.

Quart. Journ. Geol. Soc. vol. xxvii., p. 399, t. 16, f. 1–7.

C. Lyellii is the earliest known species of the genus, and is not uncommon in the Plutonia sandstones at the headland near Nun's Well, St. David's.

Formation and Locality.—Cambrian. Nun's Well, St. David's.

Conocoryphe, sp.

Pl. 5, fig. 14, (fig. 15, tail?).

A very imperfect fossil, only the central part of the head being preserved. The forward position of the eyes, which are about one-fourth down the glabella, and very near it, makes the species more like *C. Sulzeri* than any of Angelin's figured species. But the glabella is as wide in front as behind, the lobes well marked, the margin defined by a shallow punctate furrow. A short ridge connects the eyes with the glabella, and the facial suture takes a bold curve outwards beneath them; the neck furrow is near the posterior margin. It is not certain if the segments and tail, fig. 15, belong to this or the previous species; they belong to a *Conocoryphe* of large size.

Locality.—With the above, at Ogof-ddu.

Conocoryphe, sp.

Pl. 5, fig. 16.

This caudal shield, which has a broad four-ringed axis, rapidly tapering, and three curved duplicate ribs on the sides, is most probably a species of *Conocoryphe*, and may belong to one or other of the foregoing species.

Locality.—Same as above, Ogof-ddu.

Conocoryphe? simplex, Salter.

Pl. 5, fig. 17.

E. capite latissimo transverso, $\frac{4}{5}$ unciæ longo. Glabella quadrata, obtusa, truncata, lobis nullis. Oculi remoti, cum glabellâ jugo obscuro connexi. Margo anticus angustus, bene scriptus.

Distinct from any of the other Trilobites in the Upper Lingula flags, this portion of a head may receive a name. It appears to be allied to the so-called *Calymene leiostraca*, and *C. holometopa* of Angelin. But it differs from both by the less size of the glabella, which is about two-thirds only the length of the head, and must have been very wide. The reference to *Conocoryphe* is only provisional at the best. The glabella is too convex, too short and truncate in front, the eye too forward, the facial suture not direct enough beneath the eyes. And yet this genus is the nearest to which we are able to refer it.

Locality.—Upper Lingula Flags. Penmorfa Church.

Conocoryphe vexata, Salter.

Pl. 8, fig. 7.

C. capite ¾ unciæ lato, semicirculari; glabellâ brevi, longâ quam latâ depressa oblongâ rotundatâ; genus regulariter convexis; spinis brevibus; oculis medianis, ad glabellam approximatis.

An obscure species, of which we have only the head, and that is ¾ of an inch broad, and not above four lines long. The glabella as long as broad, four-fifths the length of the head and less than one-third its breadth, oblong, with rounded upper angles, not parabolic, and quite as broad forwards as behind. It is very gently convex, and shows but obscure traces of furrows. The neck segment is but slightly marked off, and the marginal furrow which runs round the flattened cheek rather faintly marked. The space in front of the glabella is broader than the narrow front margin, and is regularly and gently convex, as are the cheeks with which it is continuous.

The eye is small, placed near the glabella and half way up the head. The facial suture curves largely out both above and below the eye, cutting the posterior margin at about two-thirds out. The angle is shortly spinous. It differs from the other and allied species as much as these forms usually differ from each other. It has a much shorter head and glabella than *C. verisimilis* figured in plate 6, or *C. olenoides*, plate 8; and the absence of glabella furrows and more approximate eyes easily separates it from *C. depressa* next described.

Locality.—Railway behind Penmorfa village. Beds of passage between LOWER and UPPER TREMADOC. These beds naturally combine the fossils of the upper and lower series.

Conocoryphe (*Solenopleura*) *depressa*, Salter.

Pl. 6, figs. 1, 2, 3.

Ellipsocephalus depressus. Siluria, 2nd ed. p. 47, Foss. 7, f. 2.

C. ovata, tripollicaris, depressa, capite subtruncato brevi. Thorax segmentis 12. *Cauda* 3*-annulata. Glabella brevis, subovata, truncata, sulcis basalibus obliquis longis, reliquis obsoletis. Oculi parvi, submediani, a glabellâ dimidium diametri ejus remoti. Thorax pleuris latisulcatis, rectis truncatis. Cauda axe lato* 4*-annulato, lateribus bisulcosis.*

Our specimens are all much flattened, and the species therefore must have been a depressed one. The head is very transverse, more than twice as broad as it is long, and truncate anteriorly Of this the glabella occupies rather more than one-third in width, and is of a parabolic shape, or rather sub-oval; the lower pair of glabella furrows are distinct, oblique, and rather long. The eye is small, set rather far forward, and placed away from it for a space equal to half the diameter of the glabella. The ocular ridge is distinct. The front body rings are not quite so wide as the axis, and have the pleuræ reflexed from the fulcral point; the middle pleuræ are rather wider than their axis, and are direct to their truncated tips; only the front ones bend backward. The body becomes much narrower or attenuated behind.

A fine lineation parallel to the margin occupies a broad band round the thoracic segments, but is more conspicuous in the tail. The axis of the latter is broad and parabolic rather than conical, and reaches nearly to the margin; the side lobes have two distinct furrows.

Locality.—LOWER TREMADOC, Wern, Penmorfa; and above Penmorfa Church.

The specimen figured under the above name in Siluria was stated to have come from the upper part of the Lingula Flags, the dark slaty beds, in which it is found, were not then separated from the Lingula Flags proper. It, however, occurs in plenty with *Ogygia* and *Niobe*, and lies somewhat above the *Dictyonema* beds; so that it must be placed among the lower Tremadoc fossils.

The head was not known at first—but only the 12 body rings (the whole number) and the caudal shield; and on sending it to M. Barrande, he kindly compared it with a large unpublished species of *Ellipsocephalus*. The number of body rings is too few for the usual forms of *Conocoryphe*, but the section

Solenopleura has exactly the appearance of our fossil. In this subgenus the glabella furrows are but slight, sometimes absent; the eyes remote, with but a faint ocular ridge, and the body segments fewer. Angelin does not figure more than 11, our species has 12, and their ends are truncated, not pointed or recurved as in *Conocoryphe* proper.

Conocoryphe? verisimilis, Salter.

Pl. 6, fig. 13.

C. præcedenti simillima, nisi glabellâ longiore illobatâ genisque latioribus, oculis proprioribus. Pleuræ sulco angustissimo exaratæ, apicibus obtusis haud truncatis.

At first sight extremely like *C. depressa*, but on close examination the glabella is longer, of a parabolic form, and quite destitute of lobes. The head is truncate as in *C. depressa*, but the eyes are nearer to the glabella, the cheeks consequently broader, the neck furrows almost obsolete.

The thoracic segments are about similar in proportion to those of the species above quoted, but are abruptly narrowed in the hinder part. Their fulcrum is nearer to the axis, placed at about midway, their groove shallower, extremely narrow and sharp, instead of broad and deep, and the tips though blunt, are oblique not truncate. We have as yet found no tail.

Locality.—Above Penmorfa village. LOWER? TREMADOC.

Conocoryphe? olenoides, Salter.

Pl. 8, fig. 6.

A small species, which has so well-marked a head that it may be named *C. olenoides.*

The glabella is even longer than in the last species, all but reaching the front margin. The cheek is narrow, the facial suture in front is near the glabella, as is the very small eye, thence the facial suture takes a wide curve out, and cuts (not the posterior margin) but the outer margin, just in advance of the rounded angle. Taking this and some appearance of a projection on the front margin into account, the genus is not quite certain.

Locality.—Garth, Portmadoc, in UPPER TREMADOC.

Conocephalidæ.

Erinnys, Salter. 1864–5. Salter, Brit. Asso. Report, p. 285.

Erinnys venulosa, Salter. Quart. Journ. Geol. Soc., vol. xxviii., p. 177, t. 6, f. 1–6.

The genus *Erinnys* and its single species was named by Mr. Salter in his joint report with Mr. Hicks upon the Lingula flags of S. Wales, *loc. cit.*, pp. 284–286. The Menevian beds also (the base of thin upper Cambrian) are noticed, as the Lower Lingula flags, since then more minutely studied and constitute a group below the Lower Lingula flags. *E. venulosa* is confined to the Menevian group of St. David's, S. Wales, and the Waterfall Valley, near Maentwrog, N. Wales.

Arionellus, Barrande, 1852.

Arionellos longicephalus, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 176, t. 5, f. 20–26.

The Bohemian species, *A. ceticephalus*, Barr., allies this St. David's and Maentwrog form with the primodial fauna of that country. It is the first recorded notice of the occurrence of Barrand's genus in Britain; its place is certainly amongst the *Conocephalidæ*, a family the species in which do not range above the Tremadoc beds, is therefore essentially Cambrian and Lower Silurian.

Locality and Formation.—MENEVIAN. St. David's, Maentwrog.

Holocephalina, Salter, 1864.

Quart. Journ. Geol. Soc., vol. xx., p. 237, 1864.

The form, facial suture, glabella, and eyes (all peculiar) of this genus did not escape the discriminating eye of Mr. Salter; its affinities and differences are noticed and described in the Quart. Journ. Geol. Soc., *loc. cit.*

Formation and Locality.—Lingula Flags. Porth-y-Rhaw, St. David's. Two species only known, *H. primordialis*, Salt., and *H. inflata*, Hicks.

Holocephalina Primordialis, Salter.

Quart. Journ. Geol. Soc., vol. xx., p. 237, t. 13, f. 9.

Formation and Locality.—Lingula Flags. Porth-y-Rhaw, St. David's.

Holocephalina-inflata, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 178, t. 6, f. 8–10.

Formation and Locality.—Menevian Group. St. David's.

Placoparia, Corda, 1847.

Placoparia Cambrensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 186, t. 9, f. 1–2.

This genus and its species is essentially Arenig, occurring only in these beds, and at Llanvirn Quarry. *Placoparia* also occurs in rocks about the same horizon in Bohemia, Spain, and France, thus illustrating and uniting the faunas of the several areas. *P. Cambrensis* has occurred only at Llanvirn near St. David's.

Formation.—Upper Arenig. Llanvirn Quarry, near Abereiddy.

Angelina, Salter, 1853.

Angelina Sedgwickii, Salter.

Pl. 7, figs. 1–5.

Decades Geol. Surv., No. 11, Pl. 7, f. 1–5.

A. Sedgwickii, Salter, Siluria, 2nd ed., 1859, p. 53, fig. 2., Foss. 9. *A. subarmata*, ib., fig. 3 (specimens pressed laterally and lengthened).

Genus.—*Angelina*, Salter. Depressed, head smooth and with long posterior spines, eyes small, submedian, without ocular ridge; glabella lobeless. Body segments 14–15 with an angular fulcrum, facetted for rolling up. Tail of few (4–5) segments. Labrum emarginate.

A. ovata, segmentis trunci 15, *axe quam pleuris paullò angustiori, cauda* 2-3-*annulatâ, utrinque bispinosâ.*

The forms illustrated on our plate were part of the results of a survey by Mr. Salter in 1853 of the "Lingula flags" and overlying beds, in the mountain region extending from Tremadoc to Ffestiniog, and thence to Arenig-fawr, west of Bala.

The *Angelina Sedgwickii* was supposed, when the second edition of Siluria was printed, to belong to beds a little below the (Lower Llandeilo) Arenig zone, and these were regarded as passing down into the top of the Lingula flags themselves. A large species of *Ogygia* being associated with them render this somewhat doubtful, and the geological position is now better ascertained. This genus is characteristic of the *uppermost* portion of the Tremadoc slates.

The affinities of *Angelina* are equally balanced between *Olenus* and *Conocoryphe*. *Angelina* differs from *Olenus* by having the pleuræ grooved and facetted for rolling up, instead of flat and produced into points or spines, nor do we know of any *Olenus* that is totally without glabella furrows. It is this latter character, with the occasionally spinose tail, which distinguishes it from *Conocoryphe;* but this is combined with some characters of habit such as the long head spines, less marked cephalic furrows both axal and marginal (indicating probably a thicker crust), and the much less deflexed pleuræ with their fulcrum nearer to the axis. It wants too the ocular ridges of *Conocoryphe*.

From *Arionellus* it is separated by the less number of body rings, and that genus has a broad and expanded margin, which is without a furrow, and the facial suture so far outwards, that there evidently is but little affinity with

Angelina. The genus is named after M. Angelin, who is carefully illustrating the old rocks of Christiania. *Calymene? leiostraca*, t. xix., f. 3, of Angelin's work, may very possibly belong to this genus.

Description.—Fully three inches long, of a broad oval contour, the head blunt, and the tail only moderately pointed. The head occupies less than one-third of the length, and is semicircular, but rather truncated in front; a narrow equal margin not raised or thicker in front, runs all round, scarcely broader than the occipital border of the cheek, and continues with it; an equal space separates this margin in front from the glabella, which is parabolic, much longer than broad, and quite destitute of any lobes. It is about equal in width to the cheeks (exclusive of their margin). The cheeks are gently convex, smooth, and bear the small curved eye midway, but nearer the glabella than the marginal furrow. The facial suture is nearly vertical to them above, and then turns sharply outwards to cut the posterior margin at its outer third.

The labrum is seen on one or two specimens; (fig. 5). It has a central raised portion, separated by rather a deep groove from a flat margin, which is broadly and abruptly truncate at the apex. It is a little like that of *Lichas*, but is without the terminal notch, and differs from that of *Olenus* by its broad margin. *Conocoryphe* has a labrum without so broad a margin, and not nearly so truncate.

Thorax of 15 segments; the axis narrower than the pleuræ, gently convex, and tapering regularly backwards. The pleuræ are nearly direct, slightly produced and bent back at their ends, and grooved throughout. They are bent down a little from the angular fulcrum, which is placed at rather more than one-third in front (our figure shows it too far out at this point), and much less than one half in the middle segments. The posterior segments are scarcely at all produced or curved backwards; all the segments are facetted for rolling up. The pleural groove is deepest beneath the fulcral point, and, as beyond this the facet bounds it in front, and the posterior edge of the segment is convex beyond the fulcrum, the groove becomes an elongated rhomboidal depression; a feature never seen in those genera in which the faculty of rolling up is lost, or even very limited.

The tail is more pointed than a semi-circle, the axis not as broad as the sides, with two distinct rings, and a bluntish terminal portion not reaching the margin. The sides are marked by two lateral furrows which just reach the margin, opposite to the two short lateral spines. These furrows are duplicated. The incurved under margin (caudal fascia) is very narrow, but convex.

The compressed and elongated specimens, figs. 3 and 4, were formerly considered to be of a distinct species, not however on account of the form (which Mr. Salter was aware might in great part be due to pressure), but on account of the spinose border to the tail, a character not at the time seen in figs. 1 and 2. A noble series of specimens, distorted in every possible way, have been transmitted by Mr. D. Homfray of Port Madoc, who collected them at Mr. Salter's request, and by Mr. F. Ash of the same place.

These specimens show 15 segments, our figured specimens only showed 14, and they prove clearly that the spinose border to the tail occurs in all well-preserved specimens, yet in some more distinctly than others. And the great difference in appearance between figs. 2 and 3 is entirely due to the different direction in which they have been pressed in the stone. The pleural grooves in the one case are all but obliterated, in the other they are deepened (fig. 2), and the spinose border to the tail appears to be increased in length; in fig. 2 it is reduced. The somewhat greater space in front of the glabella, and the long head spines in fig. 3, are differences which may possibly (if they be found constant) be referable to sex.

Locality.—Upper beds of the Tremadoc slates, Garth Hill, east side of the Traeth Bach, Tremadoc, North Wales, also Portmadoc quarries, and at the Ynys Tywyn, in similar beds. (Mus. Pract. Geol.)

Fam. Asaphidæ.

A large unwieldy group of great trilobites, which are characteristic strictly of Lower Silurian rocks;—the exceptions to this geological position are very rare. The eyes are smooth, the facial suture ends on the posterior margin. The body rings 8, rarely less or more. The tail always of large size, and usually of

many segments. The labrum various in shape. While on the one hand there is some analogy with the *Calymenidæ* through the genus *Homalonotus*, the group also approaches the *Olenidæ* by such forms as *Dikelocephalus*, and ranges up to *Proetidæ* with a real affinity by means of *Stygina*, while it has abnormal and rudimentary members in *Illænus* and *Æglina*. *See* Monograph of Brit. Trilobites, Paleont. Soc. 1866.

Its geological range commences with the earliest known strata above the true primordial zone, into which if it enters at all, it can only be by such doubtful genera as *Bathyurus*, Bill.

Except in *Illænus*, it does not rise out of the Lower Silurian, and it is very rare even in Llandovery or Middle Silurian rocks. *Niobe*, *Psilocephalus*, *Asaphus*, *Ogygia*, and their subgenera, one or the other of these genera, are characteristic of every locality where Tremadoc, Llandeilo, or Caradoc strata are found. *Asaphus*, or *Isotelus*, are amongst the largest *Trilobites* known, excepting *Paradoxides* among the *Olenidæ*.

Asaphus, Brongniart, 1822.

Asaphus (*Isotelus*) *affinis*, M'Coy.

Pl. 8, fig. 15,* pl. 12, fig. 4?

Ref.—*Isotelus affinis*, M'Coy, in Synopsis Foss. Woodw. Mus., pl. 1 F., fig. 3?

It is not certain that this is identical with Professor M'Coy's very imperfect specimen, but it may eventually be included with *A. Homfrayi*.

Oblong-oval, 2½ inches long, of which the head measures more than a third, and is rounded in front; the glabella is very obscurely marked, and has no furrows. The facial suture curves boldly out above the eye, and cuts the margin considerably outside of it. Below the eye, which is more than half-way up the cheek and close to the glabella, the suture again curves largely out.

Body shorter than the head, but as long as the caudal shield. Axis broader than the sides, and not strongly separated from them. Pleuræ flat as far as the fulcrum (which is at one half in the middle rings), then curved rather than bent down. Facets broad and very well marked. Pleural groove obscure, except just beneath the fulcrum.

Caudal shield larger than a semicircle, but proportionably rather short, without segmental furrows, except the uppermost on the sides. Axis narrow, tapering, well defined, and reaching three-fourths the length of the shield; its end not prominent. Caudal fascia broad, striate.

The under side of the head has the broad epistoma well divided by a strong vertical furrow, as usual in *Asaphus*. The labrum is subquadrate, broader above and narrower towards the truncate tip. It appears not to be at all bilobed, and therefore scarcely agrees with the character of the genus. A concentric furrow and two shorter ones above it are plainly to be seen.

A. affinis resembles some Swedish species of the section *Cryptonymus*, but the course of the facial suture distinguishes it from *A. raniceps*, Bœck, though the caudal shield is like; the eyes too are smaller, and the course of the facial suture is all we have to separate it from the associated species *A. Homfrayi*; while from *A. gigas* the distinct marking out of the axis will be sufficient.

Locality.—Upper Tremadoc. Pen-y-clogwyn, S. of Portmadoc, in flinty slate, much compressed by cleavage; Garth, Penrhyn; and near Llanerch, by the road side, on the way to Treflys. Pl. 12, f. 4, was found at Tyddn Dicwm, above Penmorfa.

Asaphus Homfrayi, Salter.

Pl. 8, figs. 11–14.

Section *Isotelus?* Facial suture ending in an ogive on the upper surface. Glabella not distinct, and axis of the tail very obscurely marked out. Labrum deeply bilobed.

* Mr. F. Ash, of Portmadoc, believed that this specimen to be an imperfect form (with the front bent) of *A. Homfrayi*. It is quite possible. And in that case the two species, *A. affinis* and *A. Homfrayi*, would merge into *A. affinis*. These both differ from *A. raniceps* from Sweden by the less pronounced axis of the tail, which, nevertheless, is prominent at the end, and shows imperfect ribs.

A. (*Isot.*) *longiovatus, lentè convexus, capite ad frontem subangulato, angulis brevispinosis. Oculi submediani, parvi. Axis caudæ longus, ad apicem prominulus.*

The perfect figured specimen, lent to us by Mr. Homfray, is much elongated on the plane of cleavage; and its true length is probably not 3 inches,—the breadth $1\frac{1}{8}$: compressed as it is the measures are $3\frac{1}{8}$ by $\frac{3}{4}$ inch.

We have many specimens, in a more or less perfect state, presented by Mr. Homfray; and his cabinet and that of Mr. Ash contain very perfect examples. The head is more than a third of the whole length, and longer than the thorax, which in its turn is longer than the caudal shield. Head semioval, rather pointed in front, and with very short posterior angles, depressed broadly round the margin; the glabellar portion scarcely marked out. The eyes are placed nearly half way up the head, are small (two lines long) and with the facial suture curving out boldly beneath them, and cutting the posterior margin more than half way out from the axis. Above the eye they form a narrow ogive or diagonal rib, and nearly follow the front margin. On the underside of the head the vertical furrow on the epistoma shows distinctly through the cast.

The labrum is imperfect, but shows a strong marginal furrow, and two small lateral ones.

The body rings have the axis as broad as the sides, and moderately convex. The pleuræ are flat as far as the fulcrum, truncate at their ends, and have but a slight groove, which reaches only two-thirds their length. The fulcrum is at one-third in front, and at less than half in the middle rings. The caudal axis extends three-fourths down the smooth tail, very indistinctly marked above, but in some states crossed by several rings, and prominent at the tip. This is not quite a true *Isotelus*, but shows some tendency to unite the characters of two subgenera, *Isotelus* and *Basilicus*; the course of the facial suture is characteristic in both. It differs from its associate (*A. affinis ?*) not only by the facial suture, but by the scarcely pronounced axis of the tail. And from *A. Powisii*, with which it might be confounded by casual observers, the want of any tail-furrows except obscure ones on the axis, and the very slight convexity of the glabella, will easily separate it. It grows to only half the size of that species.

Locality.—Upper Tremadoc slate, under the Garth, near Portmadoc. (Mr. Homfray's cabinet. Railway, back of Penmorfa village; Tu-hwnt-i'r-bwlch near Portmadoc, &c. Mus. of Pract. Geol., and of Messrs. Ash and Homfray.

Asaphus radiatus, Salter.

Pl. 23, fig. 7.

Ogygia radiata, Salter in Appendix to Ray ed. of Burmeister, 125; *Isotelus laticostatus*, M'Coy (in part), Synopsis Woodw. Foss., Pl. 1 E., fig. 18, not 18*a*; *Asaphus radiatus*, Salter, Palæont. Soc. Monograph Tril., pl. 18.

A. subplanus, obtuse ovatus, capite latissimo, glabellâ distinctâ. Thorax brevis. Cauda semicircularis, untrinque costis 7-8-brevibus radiata; axe abbreviato $\frac{2}{3}$ caudæ solùm efficiente. Sulci laterales simplices, recti, breves, nec marginem attingentes. Fascia latissima valde striata.

This was for some time confounded with the Swedish fossil *Ogygia dilatata*, as it has been by M'Coy with *Isotelus laticostatus*, Green, of North America. In identifying it with the latter fossil, Professor M'Coy had chiefly in view the large specimen which he has figured (l.c. 18*a*) from the Llandeilo flags of Builth (Maen Goran). This he says agrees exactly in proportions with Green's species, and is certainly different from the Bala limestone fossil before us. His specimen is the most perfect we possess, and fell to Mr. Salter's hammer in a long and pleasant summer's work with Professor Sedgwick in 1844.

M'Coy describes and figures the entire form as obtusely oval; the cephalic shield rounded, about three times wider than long; the thorax shorter than the head, of eight slender segments; its axis rather less than two-thirds the width of the *pleuræ*, which are nearly straight, slightly bent downwards and backwards at the fulcrum, the *pygidium* nearly semicircular, its length more than half the width, and one-third longer than the thorax. Axis rather convex, narrow; it tapers gradually to the somewhat prominent tip, which reaches less than two-thirds down the tail, and is annulated by about eight furrows, leaving a small terminal unlobed portion.

The side-furrows, including the front marginal one, are about eight or nine in the adult (10 or 11 show in the young state!) and are shorter and shorter backwards, all simple, straight, or but a little sinuate; strong till they reach the broad, deeply striated, and flat or gently concave border, when they become faint and vanish. The five hinder ones scarcely reach half way to the margin. These minute details are necessary to distinguish the British species readily from such species as the *Og. dilatata*, which has duplicate, not simple, caudal ribs, bent near the end; and also from the *Asaphus nobilis*, Barrande, a Bohemian Caradoc species very like ours in the tail characters (but with a longer and more slender axis), and a cephalic shield larger and longer in proportion.

The side-furrows of our species are rather crowded at their origin, so as to seem radiating, whence the name. In *A. nobilis* they are more parallel; and the ornament on the axis is greatly more prominent in the Bohemian form.

Locality.—Caradoc or Bala limestone, Rhiwlas, near Bala (Woodw. Mus. and Mus. of Pract. Geol.); also in Caradoc shale, Co. Louth, Ireland.

Asaphus Powissii, Murch.

Pl. 15.

Siluria, 2nd ed., pl. 2, fig. 2. *Isotelus Powisii*, M'Coy, Synopsis Woodw. Pal. Foss., p. 170 (not of Portlock).

We have been able to figure this in a very perfect state from the neighbourhood of Bettws, N. Wales, and in an oblique compressed form from the cleaved slates of Dinas Mowddwy, N. Wales. Portlock's fossil is the *I. gigas*.

Locality.—Caradoc rocks, N. and S. Wales, Shropshire, Westmoreland.

Asaphus (*Basilicus*) *tyrannus*, Murch.

Pl. 13, figs. 1–5.

Decades Geol. Survey, No. 2, pl. 5; Siluria, 2nd ed. pl. 2, f. 1.

A truly characteristic species of the *Upper Llandeilo* age. Our figures are transferred from the steel plates of the Decades Geol. Survey, No. 2.

A. tyrannus is a local species. Though very like several foreign forms, it is restricted to the British area, not even ranging to Sweden, where the *A. heros*, Dalman, takes its place. Of all the sections of *Asaphus*, this one, *Basilicus*, comes nearest in habit to the *Ogygiæ*, from the whole of which, as well as from the intermediate genus *Niobe*, Ang., it is distinguished at once by the cleft labrum.

Locality.—Llandeilo, Craig-y-glyn and Craig-y-beri, near Llanarmon fach in the Berwyn Mountains, the most northerly point in Wales attained by the Llandeilo *limestone*. All the Caradoc localities given for it are spurious.

Ogygia, Brongniart, 1847.

Ogygia scutatrix, Salter.

Pl. 9, and pl. 8, fig. 8.

Siluria, 2nd ed., p. 53, Foss. 9, f. 1; Palæont. Soc. Monogr., 1865, pl. 17, f. 11–13.

O. septuncialis, fere rotunda (*aut latissime elliptica*) *depressa.* (*Caput ?*) *Thorax quam caudâ brevior, axe lato, pleuris longis, axin 1½ superantibus, profunde sulcatis, a fulcro* (*ultra dimidium posito*) *paullo deflexis. Cauda quam semicircularis latior; axi lato 8-9-annulato; limbo sulcis primariis 7-8 ad apices fractis; secundariis rectis profundis axin haud attingentibus.*

The large size and round form of this fine species much recals that of *O. Desmaresti*, (*O. Brongniarti*. Rouault), well figured by the latter authority in the Bull. Soc. Geol. France. vol. vi., 2d ser., pl. 1. From that species the less width of the axis, the straight (not curved) pleuræ, grooved nearly to their ends, distinguishes it. From *O. Edwardsii*, pl. 2, fig. 1, ib., the fewer joints of the tail, even in our much larger specimen, and the few lateral furrows, all of them duplicate, distinguishes it. The pleuræ too are curved in *O. Edwardsii*, which in very many respects resembles *O. Desmaresti*.

Our specimen may be altered in shape by the pressure accompanying cleavage; but in the figure some allowance is made for this. If not sufficiently so, still the form must have been a very wide and rounded one, and can scarcely ever have

had the shape of the species next described, although evidently closely allied to it.

Locality.—Upper Tremadoc Rocks. Northern face of the Garth hill, at the mouth of the Traeth Bach, Merionethshire, in company with abundant specimens of *Angelina* and other trilobites and shells.

A specimen crushed in exactly the opposite direction, and so lengthened out instead of widened, is figured in Pl. 8, fig. 1. This specimen has the labrum of the usual shape in the genus, but rather more pointed than usual. We also possess another specimen from the Lower Tremadoc, W. of Penmorfa, on the Caernarvon Road.

O. peltata, n. sp. (*O. Scutatrix?* var.)

Pl. 12, fig. 8.

Salter, Palæont. Soc. Monogr., pl. 17, f. 8–10, 1865.

O. modica; capite, thorace, caudâque æqualibus. Glabella lata, lævis, sulcis nullis. Thorax axi depresso, pleuris angustior, his usque ad apices falcatos nec decurvos planis, fulcro obsoleto. Cauda quam semicirculari longior; axi lato, 8-annulato; limbo sulcis primariis subrectis, secondariis abbreviatis.

From fragments in the black slate of St. David's head, this fine species must have been nearly 4 inches long, and of a broad oval shape. The head, thorax, and tail are nearly of the same length, and the whole form is greatly flattened.

Head somewhat longer than a semicircle, with short broad head-spines, margined throughout, divided nearly equally into three parts, the glabella being as broad as the cheeks, parallel-sided, and without any distinct lobes.

The eyes are large, placed half way up the head. The neck-furrow distinct, that portion of it on the cheeks much nearer to the posterior margin than that beneath the glabella. Thorax with a wide axis, not however quite so wide as the pleuræ, and somewhat narrower behind. The rings are very flat, and scalloped out at their junction with the pleuræ, so that the axal furrows present a set of re-entering angles with concave arches between them.

The pleuræ are flat, their points short-falcate, and the pleural groove is sharp and sigmoid in its curve, reaching nearly to the tip.

Tail is semicirclar, the axis occupying a quarter of the entire width, and tapering backwards. It is annulated by seven or eight furrows. The tip is blunt. The sides are radiated by eight strong grooves (including the upper or sub-marginal one), which are slightly bent downward near their ends, and are interlined by similar parallel secondary grooves, which start abruptly, as in *O. scrutatrix*, from a point near, but not close to, the axis; a plain smooth margin forms the border of the tail, and the incurved under portion is narrow and closely striated.

The specimens described are all from St. David's area, and appear to differ from the N. Welsh *O. scutatrix* in the following particulars:—More elongate in form, flatter and more pointed pleuræ, tail with a narrower axis, and only one distinct set of lateral furrows. From *Barrandia Portlocki* and allied species the much greater length of the axis will easily distinguish the two species. They belong indeed to different genera. (See Palæontogr. Monogr. 1865.)

Locality.—Arenig. Whitesand Bay, St. David's Head.

Ogygia Selwynii, Salter.

Pl. 9, figs. 2–6, and pl. 11 B, fig. 5.

Ref.—Brit. Assoc., 1852, p. 57, &c.; Siluria, 2nd ed., Foss. 9, fig. 8, p. 53; Monograph Pal. Soc., 1865, pl. 17, figs. 1–7.

We have specimens from three localities. A caudal shield from Merionethshire, and a thorax and tail from South Caernarvonshire; to these the name is intended to apply. And some larger specimens, parts of the head, and very complete caudal shields, &c., from Shropshire; these appear to be exactly the same species, and are described afterwards. Figs. 1, 2, 3, and 4.

Thorax and tail 10 lines long (the general form must have been a long-oval); thorax 9 lines broad, of eight narrow flattened segments, the axis well defined, gently convex, not quite two-thirds the width of the pleuræ. The latter are flat as far as the fulcrum, which is placed half way out, then bent down, the pleural groove very shallow, except beyond the fulcrum, where it is deeper. The tail is rather more than a semicircle, with a depressed border; it is smooth,

the ribs being faint, and only on the upper part. The axis is distinct, narrow, tapering rather rapidly at first, then parallel, and ending with a prominent tip, just within the depressed border, at rather more than three-quarters the whole length; the upper part is annulated by about five faint ribs, the rest smooth; sides radiated above by seven furrows, of which the upper one is far the strongest; the lower part is smooth. The border is rather abruptly depressed; the incurved under portion reaches to the point of the axis.

Localities.—Arenig. Fig. 1 at Hengwrt-uchaf, four miles north-east of Dolgelly; in the higher part of the igneous series (Professor Sedgwick and J. W. Salter, 1844). Figs. 2, 3, Llanfaelrhys, near Aberdaron, South Caernarvonshire. (Mus. P. Geology.)

Figs. 5 and 6, *Ogygia Selwynii*, var. *major*. Caudal shield more than a semicircle, 10 lines long by 16 broad. The axis is narrow, and tapers as in the last, but does not reach quite to three-quarters the length of the tail (in the Welsh specimens it reaches fully to that distance). It is annulated by six or seven furrows above, the upper one often the strongest, and the rest faint. The sides of the tail are marked by seven shallow short furrows, which do not reach to the depressed border, and the upper one of these also is the strongest. The incurved under portion is concentrically striate, and reaches to the tip of the axis, folding over it, and covered with concentric striæ. Head more pointed than a semicircle, an inch and a half broad, and often larger; we have been able to restore it from the parts preserved, but the sides are flattened more than our figure shows. The glabella distinct all round, depressed, gently clavate in front, but otherwise parallel-sided; marked very obscurely on the sides with one or two impressions, and having a faint central ridge near the base, and no distinct neck-furrow. The cheeks broader than the glabella, nearly flat; the large eyes placed rather less than half way up the head, and near the glabella. Margin indistinct, narrow in front of the glabella; broad on the cheeks, ending in a narrow spine posteriorly. The facial suture cuts the posterior margin more than half way out; in front it is marginal.

O. corndensis does not appear to differ much from ours in the head, except that the eyes are rather smaller and more forward, and the head spines reach to the tail; but the pleuræ are blunt-ended, deeply grooved, and strongly facetted for rolling. The axis of the tail is about the same length as in the Welch variety of our species, but the lateral furrows are strong, and indent the depressed border, while the incurved striated caudal fascia is not nearly so broad. All the furrows of the tail are much stronger, and the crust itself probably much thicker.

Locality.—Arenig. White Grit Mine, near Shelve, Shropshire; associated with *Lingula*, *Ctenodonta*, *Theca*, and *Bellerophon*. It was also found by Sir R. I. Murchison at various localities nearer to the Stiper Stones, viz., in Mytton Dingle and at Lord's Hill, and is now common in cabinets.

Niobe, Angelin, 1852.

The genus *Niobe* was formed by Professor Angelin to include those flattened species of *Asaphus* which have the lobed glabella and blunt labrum of *Ogygia*, and the facetted obtuse pleuræ of *Asaphus*. *N.* (*Asaphus*) *frontalis*, Dalman, is the type.

Niobe menapiensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 46.

Angelin's genus is well known in the Tremadoc area, and in the Tremadoc rocks of St. David's promontory. The typical form *N. Homfrayi* seems confined to the Lower Tremadoc slates of the Tremadoc district, *N. solvensis* and *N. menapiensis* taking its place in the South Wales area, where few of the Tremadoc species are common with those of N. Wales. The species *N. Doveri* (*Ether*) from the Arenig of Skiddaw has little or no affinity with either, being smaller than *N. solvensis* but nevertheless resembling it, whereas *N. Menapiensis* (Hicks) is larger than the characteristic Penmorfa and Tremadoc form.

Locality and Formation.—Tremadoc Rock. Ramsey Island and Tremanhire, St. David's.

Niobe solvensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 47

This is a much smaller form than *N. menapiensis*, but occurs with it in the same beds and at both localities.

Locality and Formation.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

Niobe Homfrayi, Salter.

Pl. 6, figs. 5–8.

Salter, Monogr. Brit. Tril. Palæont. Soc., 1865, pl. 22, figs. 3–12.

N. ovalis, depressa, lata, 3-4-uncialis; axe sub plano, distincto, caudâ semicirculari semiradiato. Glabella genis æqualis, urceolata. Oculi ante medium capitis positi. Anguli capitis obtusi. Labrum acutum. Cauda semicircularis, sulcis lateralibus 4–5, abbreviatis, interlineatis.

General shape a very broad oval, fully two-thirds as wide as long, depressed; the length between three and four inches. The axis is flattened, yet distinct throughout; wide and tapering from the broad urceolate glabella to the blunt tail-axis. The head is smooth, very little lobed, and the sides of the tail imperfectly radiated. The head is rather more than one third of the whole length, semicircular, with blunt outer angles, the glabella occupying one third the width of the head, urceolate, blunt and widest in front, then a little contracted, and thence widening again to the base, marked by a very distinct neck furrow. The glabella furrows are faint, four short ones on each side, somewhat radiating from the eye inwards, the lower one longest. The eye is very near the glabella, and placed more than half way up the head, semiluna. The facial suture reaches the edge immediately over the eye, curves boldly out beneath it, so as to leave but a third part of the posterior margin of the cheek outside it; it is marginal in front.

The body axis is broad, equal to the pleuræ in front, but narrower than those behind, and ornamented with arched striæ. The pleuræ are strongly facetted for rolling up, blunt, and rounded at their ends; the fulcrum close in to the axis in the front rings, and gradually further out till it reaches one fourth in the hinder ones. The pleural furrow is deep, but rather short.

The tail (a true semicircle) is somewhat flattened, and has a short broad axis reaching three-fourths the length of the tail, and about half as broad as the side portions, or a little more, marked by seven or eight distinct furrows nearly to the tip, which is prominent and bluntly pointed. The sides are scored by five short furrows, which (faintly interlined) only reach to the inner edge of the broad, flattened margin, and there stop abruptly. The margin is concentrically striate, of equal breadth all round. Young specimens (fig. 8) differ but little in proportion. The labrum is long and pointed, more so than in *Ogygia*, and has a concentric furrow near the margin, with a strong pair of indentations near the tip.

Locality.—LOWER TREMADOC SLATE.—Penmorfa Church, Tremadoc, and Castle Deudraeth, near Maentwrog, North Wales. Mus. Pract. Geol., Mr. David Homfray and Mr. Ash.

A much narrower variety, probably a male specimen (as suggested by Mr. Ash), is in that gentleman's cabinet. It furnished the sketch for the labrum.

Psilocephalus, Salter, 1866.

At first placed with *Asaphus* (that convenient genus being a receptacle for a good many distinct forms). Mr. Salter believed that this would form a distinct and well marked group. The small forward eye easily distinguishes it from *Nileus*, the sub-group of *Asaphus* which it most nearly resembles; and the same character, together with the eight grooved body rings, distinguish it from *Illænus*.

Psilocephalus innotatus, Salter.

Pl. 6, figs. 9–12.

Salter, Palæont. Monogr. 1866, pl. 22, ined.

P. latè ovatus, lævis, sesquiuncialis; capite valde convexo, haud trilobo, quam caudâ semicirculari multo majori; pleuris 8 planis.

This neat and rather conspicuous form is the most abundant fossil in the Lower Tremadoc beds, in company with *Niobe Homfrayi*, which is a much more rare species. Scarcely an inch and a half long, and about three-quarters broad in the largest specimens, usually one inch long, convex, strongly trilobed in the body, more faintly so in the tail, and the subspherical head destitute of trilobation or axal lines; body rings eight. The general shape is a rather broad, blunt oval; the head considerably longer than the tail, semi-oval, blunt, very convex and smooth, with obtuse outer angles, near to which the facial suture takes its rise, running obliquely inwards to the front margin, which it cuts rather within than immediately over the eye. Eye very forward, fully two-thirds up the head, small. Glabella confused with the cheeks, not at all marked out, except below (as in *Illænus*); labrum? Body strongly trilobed; the axis narrower than the sides, and tapering backwards.

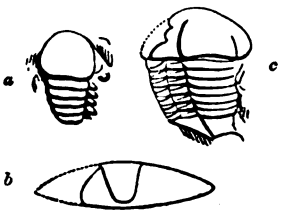
The pleuræ have square ends, are blunt, a good deal curved down from the fulcrum, which is at one fourth in front, and thence extending further and further outwards till it reaches one third in the hinder rings. The pleuræ are flat or very slightly concave as far as the fulcrum, thence sharply facetted and striated lengthwise. (The pleural groove only shows in its lozenge-shaped outward termination.) The tail axis is rather long, blunt, semicylindrical, reaching three-fourths down the tail; smooth as well as the convex sides, which have no flat or hollow margin along the striated border at all, nor any kind of furrows or ribs.

Locality.—In abundance all through the LOWER TREMADOC beds of Penmorfa and the neighbourhood of Borth and Moel-y-gest, *e.g.*, Borthwood, Tyn-y-llan, Tyddyn-llwyn farm, &c. The finest specimens were obtained in company with Mr. D. Homfray, and are in his cabinet as well as in our own. Mr. Ash has also a fine series, and the species is now in many collections.

Psilocephalus inflatus, Salter.

Woodcut 8.

Fig. 8.



P. bene trilobus, capite inflato, glabellâ distinctâ rotundâ, axe corporis prominulo caudæ brevissimæ distinctissimo.

We give a woodcut above, which, occurring at two places, appeared to Mr. Salter to differ in specific character from the *P. innotatus*. It should have been included in the plate had its full characters been perceived sooner. Head very convex; the glabella rounded, and separated by its convexity and by distinct furrows from the rest of the head. Position of eye? Body with a moderately broad, convex axis; also well distinguished from the somewhat convex pleuræ, the hinder ones of which are curved. Seven body rings have been noticed. The tail, if it belongs to the same species, is short, and has the axis not only convex, but short conical, and marked out clearly all round.

Locality.—In lower beds of the LOWER TREMADOC, north-west of Penmorfa, on the Caernarvon road (figs. *a*, *b*), and in the upper beds of the same lower series at Trwyn Cae Iago, west side of Portmadoc Harbour (*c*); also at Borthwood. (Mus. Pract. Geol.)

Illænopsis, Salter, 1865.

Ovate, head very convex, with widely divergent axal furrows reaching to the front. Fixed cheeks large; free cheeks small; the eye placed close to the *front* margin; facial suture ending on the outer margin. Pleuræ pointed, grooved.

Illænopsis Thomsoni.

Pl. 11 B, fig. 1.

Mr. Salter describes this form, though the pygidium supposed to belong to it may possibly belong to a different species: it was found in the same locality. In the head, the very forward position of the eyes is unlike that of any *Illænus* yet figured. It is true that the older *Illæni, I. arcturus*, Hall, and *I. clavifrons* of Billings, have the eye forward; but in none does it occur so forward, or so near to the glabella, as in this case. Mr. Billings does not describe the position of the eye in his *Illænus conifrons*, but from his figure it must be nearly in the same position as ours, and possibly that species may be an *Illænopsis*. *See* Geol. Canada, p. 151.

Of the thorax we have only two pleuræ, but these are quite different from those of *Illænus*, pointed and grooved; in *Illænus* they are blunt and grooveless. The pygidium supposed to belong to this (and there is the greatest probability it does so) is deeply trilobed; the axis narrow and prominent, reaching nearly three-fourths the length of the tail, and with the upper ring distinct.

Locality.—ARENIG. Bogmine, Shelve; in dark earthy shale.

Illænopsis acuticaudata, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 184, t. 9, f. 5.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, near St. David's.

Illænus, Dalmann, 1826.

Illænus Bowmanni, Salter.

Pl. 18, fig. 8.

Salter in Decade 2, Mem. Geol. Surv., *I. centrotus*, Portlock and M'Coy, not of Dalman.

One of the commonest of our Lower Silurian trilobites (Caradoc), yet not understood at all. It has a broader outline than the following, and the eye placed so far back as nearly to touch the hinder border.

Locality.—CARADOC.—Everywhere in Britain.

Illænus Hughesii, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 184, t. 9, f. 7. 1875.

This species was figured by Mr. Salter in the Palæontographical Soc. under the name *Illænus perovalis*, p. 211, t. 6, f. 5-8, and stated to come from the Llandeilo beds of Abereidy Bay. Mr. Salter was misled as to the locality and associated fossils. *Illænus Hughesii* has not occurred higher than the Upper Arenig.

Locality and Formation.—UPPER ARENIG. Llanvirn Quarry.

I. Davisii, Salter.

Pl. 18, fig. 9.

Decade 7, Geol. Survey, pl. 2.

Well distinguished by the proportion of heads, glabella, and tail, the proportion of the eye, and other characters, from other *Caradoc* species. The characters are fully described in the memoir above quoted.

Locality.—CARADOC. N. Wales, chiefly Rhiwlas, W. of Bala, also S. Scotland, as in Peeblesshire.

Barrandia Homfrayi, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 185, t. 9, f. 8.

The genus *Barrandia* first appears in the Arenig beds at Llanvirn Quarry, and ranges only into the Llandeilo. Five species are known. *B. Homfrayi* only being Arenig, the remaining four are Llandeilo. No species of this genus ranges higher.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry.

Æglina, Barrande, 1847.

Æglina grandis, Salter.

Pl. 12, fig. 11.

Siluria, 2d ed., Foss 9, f. 6. Decades Geol. Survey, No. 7, pl. 10, f. 8, and No. 11, pl. 9, f. 7, 8.

Æ. ovalis, sesquiuncialis, depressa? glabellâ tuberculatâ; axe corporis angusto; caudâ lateribus unisulcatis.

Oval (rather depressed?), 1¾ inch long; head more than two-fifths the whole length, with a large glabella without lobes, covered with rather prominent tubercles. Eyes very large, as long as the head. Body of six rings, the axis narrower than in most of the species; broadest in front, contracted behind, where it scarcely equals the pleuræ in width. These are bent at the fulcrum, which is placed rather more than one-third out from the axis. The tail is semicircular, and has rather a long-conical axis of two joints, and one obscure lateral furrow.

The largest specimen appears to have the fulcrum further inwards, but agrees in other respects with the remaining specimens; at least it has the tubercular glabella, a character in which our species differs from all others. Of the two British species previously described, *Æ. mirabilis* has a parabolic and lobed smooth glabella. *Æ. major* has a wide body axis, and two lateral furrows in the tail. The fragment figured by Salter without a name in Decade VII., pl. 10, fig. 8, appears to be quite the same, but is possibly from a higher formation. All Barrande's species have a smooth glabella, and are very much smaller, except *Æ. speciosa*, which has a very broad axis and short marginal eyes.

Locality.—ARENIG. In black slate, Whitesand Bay, south side of St. David's Head, Pembrokeshire.

Æglina, sp., eye of.

Pl. 12, fig. 12.

Decades Geol. Surv., No. 11, Pl. 4, f. 6.

The large species just figured is by no means the largest *Æglina* known. M. Barrande has an enormous one from the Llandeilo rocks of Bohemia, and we here figure the eyes (no other part occurs with them) of a great species, probably seven or eight inches long, from the upper Llandeilo flag. Contrary to the usual arrangement in the eye, the lenses are in quincunx, instead of hexagons. The eye alone measures half an inch in length! It is figured and described in the above decade.

Locality.—LLANDEILO FLAGS; Abereiddy Bay, Cardiganshire.

Æ. binodosa, Salter.

Pl. 11 B, fig. 3.

Siluria, 2d ed., Foss. 8, p. 6. Decades Geol. Surv. No. 11, Pl. 4, f. 1–6.

Æ. lata, biuncialis et ultra, convexa; capite grandi, inflato, lævi; segmento thoracis tertio binodoso; caudâ triangulatâ profundè marginatâ.

One of the most marked species of the genus, and in great plenty in the black slate of one locality. It differs so markedly from all the other species, in the triangular tail with a prolonged axis, that it is unnecessary to compare it with any. It appears to have grown as large as *Æ. grandis*.

Locality.—ARENIG. Cefn Gwynlle, in the district west of the Stiper Stones, Shropshire; in black slate, abundant. Dr. A. Fritsch, of Prague, believes he has found the same species in the lowest Llandeilo beds (*d* 1) of Prague. This is probably correct.

Æglina? caliginosa, Salter.

Pl. 11 A., fig. 10.

Æ. uncialis et ultra, lata, ovalis. Caput semiovale; glabellâ omnino lævi, nec sulcatâ; oculis angustis. Thorax segmentis 5, axe latissimo. Cauda semicircularis, axe angusto, tricostato; lateribus bisulcosis.

An inch and a quarter long, and about an inch in breadth, judging from specimens compressed in both directions. The head is a little longer than the tail, the former semioval, the latter semicircular. And there are certainly only five body rings, which fact, however, would not of itself justify the creation of a new genus. It is better left in *Æglina*. *Æ. pachycephala*, a Bohemian species much like ours, has only five rings.

Head wide semioval, regularly convex. The glabella not at all distinguished from the fixed portion of the cheeks, nor marked by any glabella furrows; the hinder angles a little prominent; the eyes (probably, for they are not preserved) narrow.

Body rings five, with an axis more than twice as broad as the pleuræ, and rather suddenly narrowing behind towards the last segment. The pleuræ increase proportionately in width, the front one being only one third the width of its axal lobe, the last one much more than half the width of the same portion. They are all obliquely truncate at their ends, and grooved throughout. The fulcrum is near the axal furrow. The tail is semicircular, with an abruptly conical short axis, of three rings; the two upper ones tolerably distinct, the third imperfect. The lateral furrows are very short, and only two show distinctly beside the uppermost one. The incurved under margin (caudal fascia) is narrow and equal all round.

There is no Bohemian species, except *E. pachycephala*, with which to compare it. And that species is so much narrower and more elongate, that there is no need to point out other distinctions. Like ours, it has only 5 rings. *E. oblongula*, Angelin, a Lower* Silurian species from Vestrogothia, is much more like our species, and were the axis broader the two forms could hardly be separated. In that figure no ribs are shown on the tail. There are five body rings.

Locality.—ARENIG. Ty-obry, Garth, near Portmadoc. Our figure is from Mr. Homfray's Cabinet; but we have many specimens, some a little larger.

Æglina obtusicaudata, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 185, t. 10, f. 3.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, St. David's.

Æglina Boia, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 185, t. 10, f. 9, 9 *a*; *ib.* Camb. Cat., p. 23.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay, St. David's.

Trinucleidæ.

A small group, yet of very common occurrence, comprising *Trinucleus*, *Ampyx*, and *Dionide*, and are the only three genera included in the *Trinuclidæ*. And this last genus shows the relation of the group to the *Asaphidæ* through *Ogygia*.

Trinucleus, Lhwyd, 1698.

Trinucleus Murchisoni, Salter.

Pl. 11 B., fig. 4.

Trinucl. Murch., Siluria, 2nd ed., p. 50, fig. 7.

T. semiuncialis, oblongus, haud quadratus, fronte radiatim punctato. Radii profundi, nonnullis brevioribus mixti. Cauda trigona, lateribus curvis, costisque brevibus binis.

* Angelin gives the locality, Besstorp, in Vestrogothia, and quotes the species from Stratum E. (Wenlock). This is probably a mistake, the genus being so completely a Lower Silurian one. *Dionide*, see p. 519, is found there.

Abundant in the black shales of the Shelve country. About half an inch long, with the lobes of the head tolerably equal in breadth, and only minutely granular (not pitted as in *T. fimbriatus*). The fringe is not very narrow, and of tolerably equal breadth along the front; the radii sunk, and with a few interlining ones in front; the ears narrow, small. The tail is half as long as broad, triangular in outline, but apparently with curved sides from the sinuous outline of the bent portion. This is very broad, even for this genus, and is only oblique, not abruptly bent down. The axis, with many prominent ribs, is carried over it. The sides, however, which are concave, have only two or three short curved ribs, while in *T. fimbriatus* there are at least five straight ones which reach the margin. It is very like *T. fimbriatus*, from which it differs in several important particulars.

The shape is longer. The fimbriate border in front has interposed shorter rays, the body rings are broader and the tail longer, with a more curved outline, and with only two lateral curved ribs. The incurved fascia is not vertical, but very oblique, and the axis is continued over it.

ARENIG. Cefn Gwynlle; and other places near Shelve.

Trinucleus Sedgwicki, Salter.

Pl. 12, fig. 9.

T. uncialis? latus, capite semicirculari reticulato-punctato, glabellâ subpyriformi, genas vix superante, lateribus bisulcatis; fimbriâ angustâ, concava, punctis radiatis, in series 5–6, quorum duobus exterioribus majoribus in sulco positis, collocatis; reliquis minutis transversis, nonnullis irregularibus et ad latera confusis; angulis posticis haud dilatatis.

Of this species we have but a few specimens. It differs at once from the common *T. Gibbsii*, its associate, in the want of any facial line. It is more nearly like *T. Lloydii*, Decade 7, pl. 7, from which it differs by the glabella being extended a little into the fringe, and by not having any expanded angles to the head. The fringe, too, is narrower, and has more unequal puncta, the outer two rows being large and sunk in radiating furrows, the inner rows not strictly regular, and more in number than the outer rows. The surface of the head, too, is closely punctate. It is quite possible this and the next may be varieties of *T. fimbriatus*, but at present they must be kept distinct.

Locality.—S. side of St. David's Head; Cae-glyd, Manod Bach, near Ffestiniog. In the "Arenig" rocks.

Trinucleus Gibbsii, Salter.

Pl. 12, fig. 10 (somewhat enlarged).

T. Gibbsii, Siluria, 2nd ed., p. 53, Foss. 9, fig. 7.

As broad as long (excluding the long divergent head spines, which reach back beyond the pointed tail); fringe narrow, punctate in radiating rows.

The head is transverse, but squarer than usual in the genus, with a fringe border only wide in the central part, and considerably so,—the fringe widening here to meet the glabella, which is shorter than the cheeks, and having in its furrows at least four or five puncta; while round the cheek they are reduced to two, and only become three or four again at the small posterior triangular ears. The spines start abruptly, are but slightly curved, and diverge but little, so as not to make with each other and the head an angle greater than 50°. The glabella is not more than one quarter the width of the head, and is short-pyriform, very clavate and blunt in front, quite narrow and marked with two distinct side-furrows behind. Its base is particularly narrow, and the neck furrow strong. The cheeks are spherico-triangular, rather convex, and reticulate over all the space behind a very strong ridge which bisects them, occupying the place of the facial suture. This ridge is curved forward, so as to divide the cheeks into two very unequal portions; where the continuous neck furrow abuts upon this ridge, at the posterior angle, it becomes a deep and broad hollow, almost a pit; and a similar deep excavation is established at the junction of the ridge with the front margin of the glabella.

The body has six flat rings, and is as long as the head without including the fringe, and not quite so broad; it has an axis one quarter its breadth, and

tapers back to the tail piece, which is sharply triangular, and pointed; its length is one third its width, the axis being therefore broader in proportion than in the body rings. Three or four ribs are seen on the axis, which is fusiform, not conical, and extends to the very apex. No side ribs, the lateral portions of the tail being quite flat and smooth.

Locality.—ARENIG. S. side of St. David's Head.

Trinucleus concentricus, Eaton.

Pl. 19, fig. 4.

T. Caractaci, Sil. System. *T. concentricus* of Eaton, 1832, and now of most authors.

We have repeated the generalised figure of this common fossil, which was given in the Memoirs of the Geol. Survey, vol. ii., pt. 1. And the peculiarities of the very simple fringe are given in fig. 4 *a*. It is remarkable for its simple flat expansion; a single keel on its lower edge, behind the two front rows of pores, alone breaking the uniformity of its shape. In most other species there is some variety in the ornamentation of the fringe. Either the pores are sunk in radiating furrows, as in *T. fimbriatus*, or they are enlarged at the outer angles as in *T. favus*, or the fringe is curved suddenly down as in *T. seticornis*, or concave as in *T. Lloydii*, or doubly convex as in some French forms.

In this fossil, as in the cognate forms, *T. Goldfussii* and *T. ornatus* of Bohemia, the fringe is flat above, and of nearly regular width throughout. But it is subject to variations in proportion, which variations are fully discussed in Decade 7 of the Geol. Survey.

Locality.—CARADOC rocks of Britain everywhere. UPPER LLANDOVERY; Shropshire, very rare, but certainly present (Lightbody and Salter).

Trinucleus favus, Salter.

Pl. 13, fig. 9.

T. concentricus, var. *favus*, Salter in Memoirs Geol. Survey, vol. ii., pt. 1, pl. 9, fig. 3, and in Decade 7, pl. 7.

T. modicus depressus glaber, capite quadrangulo, fimbriâ latâ, ad angulos rectos externos favosâ. Glabella parva. Spinæ genales divaricatæ.

Mr. Salter fully recognised this remarkable form as a distinct species. It is extremely common in S. Wales, always in Llandeilo rocks, and is also found in the patch of Llandeilo limestone, which appears so strangely introduced into the network of faults on the east of the Berwyn Mountains, N. Wales.

Mr. Salter did not agree with Prof. Wyville Thomson and M. de Barrande, that the facial suture in *Trinucleus* runs round the margin, but believed that its course is marked out by the obscure line which runs obliquely across the glabella, and that the fringe is simply a variation of marginal ornament, in fact a set of coalesced marginal spines. Moreover, the indications of eyes in some forms of *Trinucleus* (or *Tretaspis*, *T. seticornis*, &c.) favours this view.

Locality.—LLANDEILO. N. and S. Wales.

T. Ramsayi, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 183, t. 10, f. 2. 1875.

Locality and Formation.—UPPER ARENIG and LOWER LLANDEILO GROUP. Porth-Hayog, Ramsay Island, St. David's.

Trinucleus Etheridgii, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 182, t. 9, f. 6. 1875.

Formation and Locality.—UPPER ARENIG. Llanverin, St. David's.

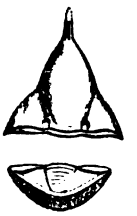
Mr. Tawney has lately obtained this species at Penarfynydd farm, betw Rhiw and Llanfaelrhys, at the S. extremity of the Lleyn, probably in Are beds. It is associated with *Didymograptus bifidus* and an *Obolella*.

Ampyx, Dalmann, 1827.

Ampyx tumidus, Forbes.

Pl. 23, fig. 6. Woodcut 9.

Fig. 9.



A. tumidus, Forbes in Decade 2, Mem. Geol. Survey, pl. 10, p. 4.

A. capite elongato brevispinoso, caudâ brevissimâ. Glabella maxima, obtusa, carinata, postice convexa, paullulum contracta, anticè in spinam brevem sulcatam, haud abruptè producta. Genæ parvæ, vix dimidium glabellæ attingentes, sulco postico distincto; spinis? Cauda bis quam latâ brevior, omnino lævis, nisi axe lato sulcato, lateribus margini deflexo latissimo.

Though only indicated by Forbes in the Decade above quoted, the species is a distinct one in a genus remarkable for the number and similarity of its species.

We have but the head and caudal shield, in plenty. The former, as may be seen by the lengthy diagnosis given above, is greatly elongate in front even for this genus, *i.e.*, the body of the glabella itself is lengthened out, and is also broad; it is most convex behind, where it is but little contracted, and furnished with a single short lateral lobe, not well shown in our figure; but these lobes are less approximate than in the *Amp.* (*Raphiophorus*) *depressus* of Angelin, a Lower Silurian Swedish form, most like our species of any, yet with the glabella far too short, and cheeks and pygidium too long.

As for *Ampyx tumidus*, "It is nearly allied," says Forbes, "to *A. rostratus*, Sars., but differs in having much smaller cheeks in proportion to the glabella, which is even more produced than in the *A. rostratus*, and exceedingly tumid. The cheeks in the species compared are beyond the middle of the glabella; in the British form never so far as that part. The neck lobe, too, of the latter is narrow; and the tail, though similar in sculpture, is much shorter and wider." Professor Forbes also compares it with *A. Bruckneri* (Boll, in Dunker and Meyer's Palæontographica, 1 Band., t. 17, fig. 8), a species with a carinate glabella; with *A. Portlockii*, Barr., which has a contracted glabella, while ours is elongate; and, lastly, with *A. Bohemicus*, Corda, a form with wide glabella, minute tail, and no rings on the axis.

Locality.—CARADOC limestone, Rhiwlas, Bala.

Ampyx prænuntius, Salter.

Pl. 8, fig. 5.

Ampyx (*proævus majorum stirps*), *minutus. Glabella brevis, haud ad marginem angustum producta, sulcis obliquis lateralibus. Axis segmentis* 6. *Cauda subtriangularis costulata, axi abbreviato.*

(*Specimina tria compressa in museo cl. F. Ash tantum vidi.*)

A minute species, which has the peculiarity of showing only a semioval, not triangular head, with a very short glabella, not elevated in front, and with a very oblique lateral furrow on each side. It is not clavate or gibbous, only convex forwards, and not at all produced beyond the slightly angular front margin, which has a narrow convex rim all round it.

The body is very little different from that of other species, of six rings, with a rather wide convex axis. The tail is only sub-triangular, and somewhat rounded, with a short convex axis, and two or three ribs on the sides.

We have only seen three specimens; they are on a single slab, and were detected by the keen eye of Mr. F. Ash. *A. prænuntius* is unquestionably the oldest species of the genus yet known.

Locality.—UPPER TREMADOC. Pen-y-clogwyn, Tremadoc.

Ampyx Salteri, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 182, t. 10, f. 7, 8. 1875 *ib.* Camb. Cat., p. 22.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay, St. David's.

Dionide, Barrande, 1846.

Dionide atra, Salter.

Pl. 11 A., fig. 9.

D. maxima. Cauda plana triangularis, ¾ unciæ lata, et longa; axe haud convexo angustissimo, longo, 20-annulato; lateribus subconcavis; sulcis obliquis 20, ad medium retrorsum fractis nec marginem attingentibus, per dimidium interlineatis.

We have only the caudal portion; and yet, so characteristic is this portion, that there can be little doubt of the genus. It fell to Mr. Salter's lot to disinter the first specimens, when searching the dark slates at the farm of *Ty obry*, near Garth; and our Tremadoc friends appear as yet to have discovered no more of this fine species, which is as distinct from either the Bohemian form *D. formosa*, or the Swedish *D. euglypta* (from Besstorp*) as we could wish. From both species the extremely narrow axis of the tail separates it.

Length and width of the flat triangular caudal shield about three-quarters of an inch, the extremity rounded, not acute; the long thin-pointed axis nearly reaching to the end, regularly conical, acute, not widening above, where it is certainly not one third the width of the side lobe (while in the other species it is nearly half its width). It is annulated closely by about 20 distinct rings, and by more imperfect ones. The side lobes, which are slightly concave round the margin, have 19 or 20 oblique furrows which are abruptly bent down (*fracti*) at about half way out, and remain of the same strength nearly to the margin, which is quite plain, and apparently not at all striated concentrically. The ribs are interlined for the first half only, and the appearance thus given is that of a great multitude of ribs. Indeed there is no genus, except *Encrinurus*, which shows so many on the axis, and none at all which has them so numerous upon the sides.

Locality.—ARENIG. Ty-obry, in dark slate. (M. P. Geology.)

Microdiscus, Emmons, 1855–6.†

M. punctatus, Salter. Quart. Journ. Geol. Soc., vol. xx., p. 237. ? Young of larger Trilobite.

A genus of doubtful position in classification. The nucleal spine would remove it from Trinucleus proper, and the strongly margined cephalic shield adds still more doubt as to its belonging to the family in which it is provisionally placed.

Formation and Locality.—LINGULA FLAG. Porth-y-rhaw, St. David's.

Microdiscus sculptus, Hicks.

Quart. Journ. Geol. Soc., vol. xxvii., p. 400, t. 16, fig. 9, 10.

The only other species found in Britain is *M. punctatus* from the Menevian beds of Maentwrog. The difference in species is manifest from the structure of the pygidium.

Formation.—LONGWYND GROUP. Headland, near Nun's Hill, St. David's.

Cheiruridæ.

We include in this the following groups:—*Cheirurus* and its subgenera; *Sphærexochus; Staurocephalus, Deiphon, Encrinurus*, and *Cybele.*

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* Clearly this is a Lower Silurian locality, and therefore *Æglina obi* with it, is also Lower Silurian. *Æglina* is not a primordial fossil.

† American Geology, vol. i., p. 116, t. 1, f. 8. (Taconic strata.)

Cheirurus, Beyrich, 1845.

Cheirurus Frederici, Salter.

Pl. 8, fig. 1–3, and Woodcut 10.

Paleontogr. Soc. Monogr. Brit. Tril., Salter, pl. 5, figs. 18–21.

C. (Eccoptochile) uncialis et ultra. Glabella oblonga parallela, seu anticè angustior, sulcis distinctis radiatis, lobo antico parvo trigono. Genæ punctulatæ. Pleurarum sulci simplices exarati, apices longispinosi. Cauda major, 6-spinosa, spinis longis, rectis, subparallelis.

This Tribolite, only found as yet in the upper part of the Tremadoc slates, is a member of a genus more characteristic of higher beds (Lower Silurian). There cannot be much doubt about the genus, unless it may be referable to *Placoparia*, which has not, so far as known, the punctate cheeks visible in this specimen, and has nodular, not furrowed, pleuræ. *Eccoptochile*, Corda, is the nearest in character; and the fine species, *E. Sedgwicki*, described by M'Coy, is the only British species we have to compare it with. From that fossil the closely punctate cheeks and parallel-sided glabella greatly distinguishes it, and there are some other points of difference in the elongated pointed spines and deep simple pleural furrows of the body rings and tail.

Description.—Occasionally as much as 3½ inches long, and rather wide (all our specimens are much compressed). The head is wide, semicircular, or less; the outer cheeks, occupying the greater part of the head, are strongly punctate, margined all round by a continuous furrow, and produced into a long head spine,—the border smooth. The eye very far forward, as in *E. Sedgwicki*, and the facial suture rising so high as to cut the outer margin much in advance of the middle of the head, separating a very small free cheek. The glabella is not nearly so wide as the cheeks; it is parallel-sided, apparently not much longer than broad, and has the furrows very distinctly marked. There are three on each side, and rather deep, all straight and inclined a little upwards; the front ones especially, so as to have a radiate appearance. They reach more than one-third across the glabella, and thus leave but a narrow space down the centre. The front lobe, marked out by the two converging front furrows, is a wide triangle, and does not occupy more than a third of the length of the glabella. The surface is granulated, not punctate.

Thorax, in one tolerably perfect specimen in Mr. Homfray's cabinet, apparently composed of only 11 flat rings, of which the axis is not so wide as the pleuræ; these last are convex and *deeply grooved along the middle*, almost to the ends, which are produced into a long sharp spine, bent backward in all the segments, but most so in the posterior ones, in which the spines are fully equal to the length of the pleuræ themselves. If the thorax has 11 rings, the tail, which can hardly be distinguished from it, appears to have only four or five joints on the axis, and three short pleural lobes on each side, which are grooved throughout as strongly as and like the pleuræ of the body rings.

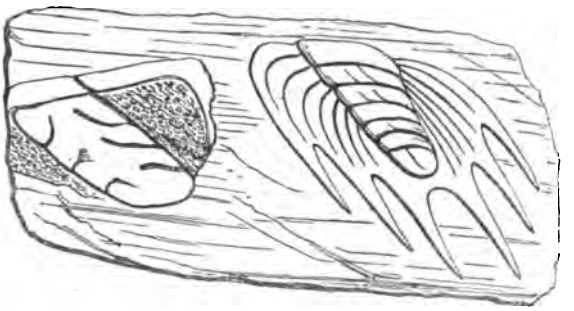
C. (E.) Sedgwicki, according to M'Coy's figures, has a much more complex tail. But the resemblance is very close, except in the number of tail spines, to such species as *C. Eryx*, Billings,* from the Quebec limestones, and Mr. Salter knows no other with which it can be directly compared.

A larger specimen, however, found by Mr. Homfray since this description was written, has six distinct joints to the axis, besides the terminal one, which is small, and three pointed pleuræ on each side, each about as long as the limb is broad,—and directed backwards, not much outwards. It is here figured: the specimen is in Mr. Homfray's cabinet.

The species is named after Mr. Frederick Ash, of Portmadoc, to whose good services with regard to the geology of this part of N. Wales such frequent references have been made.

* Canadian Naturalist and Geologist, vol. v., p. 322.

Fig. 10.



Cheirurus Frederici, distorted specimen.

Locality.—UPPER TREMADOC slate. Garth, Tremadoc. (Mr. Homfray's cabinet.)

Cheirurus juvenis, Salter.

Pl. 18, figs. 1, 2.

Cheirurus clavifrons, Salter and M'Coy, not of Dalman. *C. juvenis*, Salter, Mem. Geol. Survey, vol. ii., pt. 1, pl. 7, figs. 1–3; Decades Geol. Survey, No. 7, p. 12. Paleont. Soc. Monogr. 1864, pl. 5, f. 9–12.

It does not appear to range to America, and certainly does not cross the British Channel into the Lusitanian province.

Locality.—CARADOC. Bala, N. Wales; Westmoreland; Ireland.

Cheirurus octolobatus, M'Coy.

Pl. 18, fig. 3.

C. clavifrons, Dalm.? Salter, Mem. Geol. Survey, l. c., pl. 7, fig. 3. *C. octolobatus*, M'Coy, Woodw. Pal. Foss., t. 1 G., fig. 10; Salter, Paleont. Monogr. B. Tril. pl. 5, fig. 13, 14.

A small species, of which we formerly only knew the caudal portion. It has lately been figured perfect; it had a globular glabella and a truncate 8-spined tail.

Locality.—CARADOC. Bala.

C. bimucronatus, Murch.

Pl. 18, figs. 4–6, and var. fig. 7.

Sil. System, pl. 14, figs. 8, 9; Salter, Decade 7, Geol. Survey, pl. 2; Paleont. Monogr., pl. 6, figs. 9–18.

We have reproduced here the principal figures of this really large and very common Trilobite, which ranges from the CARADOC to the LUDLOW rocks inclusive, over the British Isles. Some of the finest specimens we have seen were found in Caradoc limestones, Kildare, and also at Sholes Hook, Pembrokeshire (fig. 5). The fossil becomes smaller, though still abundant, in Wenlock rocks (figs. 4–6), and in more sandy strata assumes occasionally an extra prong to the caudal shield (fig. 7).

Encrinurus, Emmerich, 1845.

Encrinurus sexcostatus, Salter.

Pl. 19, figs. 5, 6.

Decades Geol. Surv. 7, pl. 4, figs. 1–11 (*Zethus*, M'Coy in Pal. Foss. Woodw. Mus.), *Cybele sexcostata*, Salter, Mem. Geol. Surv., vol. ii., pt. i., pl. 8, fig. 10 (only).

An interesting Lower Silurian form of a genus far more common in Upper Silurian rocks. The present species is not unfrequent at Bala, in N. Wales, and Haverfordwest, in Pembrokeshire; it is not known in other localities. It is remarkable in the genus for the bluntness of the tail, and the small size of the tuberculation on the head. The eyes too do not appear to have been so large and prominent as usual in *Encrinurus*.

Locality.—CARADOC. Bala, &c., N. Wales; Sholeshook, &c., near Haverfordwest, S. Wales.

Cybele, Lovèn, 1845.

Cybele verrucosa, Dalm.

Pl. 19, fig. 7, head only.

Part of *Cybele sexcostata*, Salter, in Mem. Geol. Survey, vol. ii., pt. 2, pl. 8, fig. 9 (only). *C. verrucosa*, id., in Decade 7, pl. 4, p. 4. *Cybele*, Lovën. *Atractopyge*, Hall and Corda. *Zethus*, M'Coy.

In the work above quoted, this is figured as the head of *Encrinurus* (*Cybele*) *sexcostatus*, but we had not then found the perfect trilobite. It is corrected in the Decade above quoted. For Angelin's complete figure of the *Cybele verrucosa* shows how very near that genus approaches, in some of its species, to the genus *Encrinurus*. There is the same clavate shape of the glabella, a similar set of furrows on it, viz., 4 distinct pits on either side, and the same clavate eyes as in *Encrinurus*. But there are 12 rings in *Cybele; C. bellatula* (*Calym.* of Dalm.) has certainly 12*, and the 6th ring in this species has a decided protuberance at the end, showing a tendency towards the fuller development of spines on the hinder segments of *Zethus*. All this differs from the Russian species described by Pander and Volborth as *Zethus verrucosus*, in which the glabella is not clavate, and the hinder pleuræ only are abruptly lengthened out.

Zethus bellatulus (*Calymene bellatula*), Dalman, however, sent us by Professor Volborth, has the shape of *C. verrucosa*, and Salter proposed, therefore, to keep these in the genus or subgenus *Cybele*, distinguishing it from *Encrinurus* by the number of segments (12), which in the principal species, *C. verrucosa*, are all lengthened out into long spines.

The genus *Zethus* is retained only because the name is extant, and the species *Z. verrucosus*, Pander, fully described and figured by the careful Volborth; for the *genus Zethus* was founded chiefly on a glabella of one of the *Cheiruri* (*see* Decade 7, pl. 4, p. 1), and *Cryptonymus* must be rejected entirely. It was originally intended for certain *Asaphi* by Eichwald, who afterwards, seeing his mistake, endeavoured to restrict it in 1840 to the tuberculate species now called *Encrinurus*. But Emmrich appears to have neglected this, and sufficiently indicated the genus *Encrinurus* in his scientific essay, 1845; M'Coy adopted and described it in 1846, since when the genus has been universally adopted. No good would be gained by reverting to the appellation *Cryptonymus*, and the name itself is objectionable in many respects. It may stand for a subgenus of *Asaphus*, as Angelin has already proposed.

Lichadæ.

Perhaps if we include in this abnormal group the genus *Lichas* and its sub-genera, we shall be going as far as our materials permit us at present to do.

Lichas laxatus, M'Coy.

Pl. 19, figs. 1, 2, 3.

L. laxatus and *Calym. forcipata*, M'Coy, Synopsis Sil. Foss. Ireland, t. 4. *L. laxatus*, Salter, Memoirs Geol. Surv., vol. ii., pt. 1, pl. 8, figs. 4–6.

Locality.—CARADOC. A fine species, very common in N. and S. Wales.

Calymenidæ.

Calymene, the most beautiful form in the whole order, and *Homalonotus*, its anomalous ally, are found wherever Silurian rocks occur. It is probable that

* I should certainly prefer to regard *Cybele* as thus defined, viz., *C. bellatula*, *C. verrucosa*, as a sub-genus only of *Encrinurus*. The *Zethus verrucosus*, Pander, is quite a different fossil, and may fitly become the type of another sub-genus or genus, as above said.

both of these genera transgress a little the upper limit of the Silurian system. *Homalonotus* certainly does. And it is certain that they begin with its lowest strata immediately above the primordial series or the Arenig.

Calymene, Brongniart, 1822.

Perhaps one of the most typical forms of Trilobite, and differing from all other genera in having the surface of the eye of soft texture.

The species differ only in slight particulars, at least in the larger part of the 20 or 25 forms known. Some, however, have marked and distinguishing characters. The common *C. Blumenbachii* is at once the most widely spread and the longest lived; for it is known both in the Lower and Upper Silurian rocks of Europe and America. It has been divided into several forms, which cannot claim more than the rank of subspecies, as they pass by slight gradations into forms which no author has yet thought it right to separate from the type species. *Calymene cambrensis* and *C. brevicapitata* Mr. Salter describe as varieties or subspecies only; they are recognisable forms. And if they should be regarded as species, their relative value is still the same.

A plate of the various species of this genus is given by Salter (pl. 17), ascending from the Arenig to the highest beds of the Lower Silurian, in order to show the gradations between the so-called species in the Caradoc and Llandovery beds, and the real distinction between these and the Llandeilo species. The genus began with the Arenig and continued to the close of the Silurian system, the bounds of which, as above said, it only slightly transgresses.

The grouping of the species is as follows, in Britain :—

Arenig group - - -	*C. parvifrons.*
Llandeilo - - - -	*C. duplicata, C.cambrensis, C.Tristani.*
Caradoc - - - -	*C. Blumenbachii, C. senaria.*
Lower Llandovery - -	*C. Blumenbachii.*
Upper Llandovery (May Hill group)	*C. Blumenbachii.*
Wenlock - - - -	*C. Blumenbachii, C. tuberculosa.*
Ludlow - - - -	*C. Blumenbachii.*

It will be seen, therefore, that while other species are short-lived, the common *C. Blumenbachii* or Dudley Trilobite has lived through a variety of conditions; hence it has varied much. *C. cambrensis* and *C. senaria* are sub-species only, as there are scarcely any tangible differences except those of proportion; hence the British species would be only four.

C. parvifrons and *C. duplicata* are sufficiently distinct from all.

Calymene parvifrons, Salter.

Pl. 12, fig. 3.

C. parvifrons, Salter, Appendix, Pal. Foss. Woodw. Mus., 1851, pl. 1 F., fig. 7; Paleontograph. Trans. Monog. Trilob., 1865, pl. 9, figs. 25–28.

C. biuncialis et ultra, modicè convexa, sublævis; capite subtrigono, fronte valde productâ, convexâ, fere gibbâ. Glabella angusta, brevissima. Genæ convexæ, oculis remotis, subcentralibus. Cauda lata, axi convexo, lateribus curvatis, costis per totum interlineatis.

About 2 inches long, the head subtriangular, and with a much produced front, equal in length to the glabella, which is about half that of the whole head. The glabella is short, parabolic, much narrower than the cheeks, which are convex, smooth, and have the eyes subcentral. The axis of the body is convex, narrower than the sides. The tail is wider than long, with a convex narrow axis, more prominent towards the tip, and the sides excessively convex and curved down, with five ribs, fully interlined from near their origin.

This is sufficiently distinguished by the very small size of the glabella; and as it is fully described in Mr. Salter's monograph loc. cit., need not be treated of more fully here. The *C. duplicata* is nearer than most, but has far too narrow an axis and too flat a form; moreover the shape of the glabella is much narrower.

Localities.—Arenig. Tai-hirion, on the Bala road, west of Arenig mc (Coll. by Prof. Sedgwick and J. W. Salter). Under Manod Bach, Ff (Coll. J. W. Salter, 1853); Ty-obry, Penrhyn, Tremadoc; west of Stiper Shropshire, abundant.

Calymene Blumenbachii, Auctorum.

Pl. 17, figs. 1–7.

C. spectabilis, Angelin, Pal. Succ., t. 19, fig. 5. *C. Blumenbachii. See* Monog. Brit. Tril., Pal. Soc., pl. 8.

Typical specimens of this common fossil have the axis very broad and convex, the sides being curved and steeply bent down from the fulcral point. The glabella is also very wide and blunt in front, and scarcely any space divides it from the thickened but not produced front margin. The granulation too, especially of the head, is coarse and unequal.

The tail follows the character of the thorax, and is convex, with short triangular sides. There are about seven distinct rings on the axis, and five forked lateral ribs, and the sides of the tail slope rapidly away from the axis.

In our figs. 1–4 we have but little departure from these type characters. The front margin is not quite close to the glabella, and is somewhat more elevated. The body rings do not bend down so steeply, and in like manner the sides of the tail are more curved outward, so that it presents a more semicircular and less triangular outline.

These are only slight differences, yet they are such as exactly lead on to the greater variations observable in the var. *Caractaci*, and thence to *C. senaria*.

Our figs. 1–4 is from Lower Llandovery rock. The same form has been figured from the CARADOC of Ireland.

C. Blumenbachii, var. *brevicapitata* (or *Caractaci*).

Pl. 17, fig. 9.

SYN.—*C. brevicapitata*, Portlock, Geol. Rep., pl. 3, fig. 3.

Salter, Mem. Geol. Surv., vol. i., pt. 1, pl. 11, figs. 1, 2; *C. forcipata*, M'Coy, Sil. Foss. Irel., pl. 4, fig. 14, head only. *C. senaria*, Salter, Monog. Brit. Trilob., pl. 9, figs. 3–5. *C. brevicapitata*, Portlock's Report, second variety (*C. senaria*, Conrad, Ann. Geol. Rep. N. York, p. 49, 1841). Salter, Mem. Geol. S., l. c., pl. 17, figs. 10–12.

In these varieties or species the glabella narrows more in front, yet is not truly triangular, except in the second variety, which Mr. Salter believed to be a good subspecies. It is the *C. senaria* of Conrad, as above quoted, and is the more common. In the event of considering this a distinct form, it would be better to suppress the term *brevicapitata*, and replace it by the term *C. Blum.* var. *Caractaci*; as Portlock evidently intended the form with the shorter glabella (*see* Monog. of Brit. Trilobites, above quoted). The front is produced and recurved, the margin not thickened or appressed against it, but projecting forwards. In the second variety the general shape of the head is triangular (the specimens figured by Portlock being only accidentally shortened by pressure). The axis is broad, and the sides of the tail curve more outwards than in the typical variety, and less than in the next described one, *C. cambrensis*. The coarse granulation of the surface is absent, too, as in that variety.

C. parvula of Barrande is much like *C. brevicapitata* (or *C. senaria*) in shape. Good specimens of the former, however, show a depressed glabella with shallow straight furrows, and a ridged front. It is altogether distinct.

Localities.—CARADOC rocks of Shropshire (figs. 7–9); of Bala and North Wales (figs. 11, 12); of Tyrone (fig. 10).

C. Blumenbachii, var. *Cambrensis.*

Pl. 17, figs. 13, 14.

C. brevicapitata (part), Salter, Mem. Geol. Survey, vol. ii., part 1, pl. 11, figs. 3–5 (not 1, 2). Monogr. Brit. Trilob., 1865, pl. 9, figs. 12–14.

C. modica elongata, alutacea, glabellâ brevi, caudâ incurvâ. Frons producta subrecta. Glabella trigona, lobis utrinque binis, tertio obsoleto. Cauda axe angusto; lateribus valde curvis multisulcatis, sulcis binis.

This variety, or species, for it may be so considered though hitherto confounded with *C. brevicapitata*, differs in the following particulars:—

The glabella has only two distinct lobes, the upper lobe being minute and all but obsolete, thus (as in *C. pulchra*, Barr.) giving a "*fleur de lis*" appear-

ance to the glabella. The anterior margin projects straight out, and is not at all recurved. The general surface is finely granular.

The tail differs still more from the typical form (which has sloping sides and only five partially forked ribs). The sides in *C. cambrensis* are greatly curved, *see* fig. 5 in the above plate.

The difference or distance, so to speak, between the variety here called *C. cambrensis* and the Caradoc variety, *C. brevicapitata* or *senaria*, is more considerable than between this last and the ordinary type; or rather the short interval is not bridged over by known connecting varieties. Mr. Salter retained it as a variety or sub-species.

Formation.—LLANDEILO. Throughout South Wales, abundant.

The *Calymene parvifrons* above described has a still shorter glabella, and its front so much produced that it cannot be properly identified with any of the varieties of *C. Blumenbachii*. But even this is not so remote a form as the *Cal. duplicata*, a fossil which occurs with the *C. cambrensis* in the Llandeilo rocks, and which is next described.

[*C. Blumenbachii* seems indifferent to its habitat, living either in sand or mud, and is occasionally found in limestone, and, to judge from its wide range and its associates, it must have lived at various depths of water. *C. parvifrons*, on the other hand, has only yet been found in beds which have evidently been formed in shallow water; and *C. duplicata* has hitherto been found only in black shale, and is possibly a deeper-sea form.]

C. duplicata, Murch.

Pl. 17, figs. 15, 20.

Salter in Siluria, 2nd ed., pl. 3, fig. 6. Monog. Brit. Trilob., 1864, pl. 9, figs. 19–24.

C. sesquiuncialis, punctata, depressa, fronte vix productâ. Glabella parallela, longa. Oculi antici. Axis corporis angustus, caudæ longus præangustus, nec quartam latitudinis efficiens. Costæ interlineatæ.

An inch and a quarter long, and about seven-tenths broad, with a scarcely produced front, not above one-third the length of the glabella; a very narrow axis, and a many-ribbed tail.

The glabella is rather parallel-sided than parabolic, one-fourth only the width of the head (in the ♀ form broader), with three well-marked lateral lobes, the lowest not greatly projecting beyond the others, depressed, not rising above the level of the broad gently convex cheeks, on which the small eye is placed very forward, and half the width of the glabella from it. The neck-furrow is sharp, the axal furrows narrow and deep; the surface of the head is finely granular.

The body has a very narrow, rather convex axis:—in some specimens less than a fourth the width of the whole. The pleuræ quite flat, as far as and beyond the fulcrum, then curved abruptly down. The pleural groove is sharp and narrow, the fulcrum remote in front, and nearly at one half behind. The tail is semioval, with a very narrow long axis, all but reaching the margin. It is long-conical, marked by nine or ten ribs, and is so narrow as not to occupy more than one-fifth the whole width of the depressed caudal shield. The side lobes have seven curved furrows, interlined throughout by shallower lines.

Formation and Localities.—LLANDEILO. Builth, abundant; Abereiddy Bay, Pembrokeshire.

Calymene Hopkinsoni, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 187, t. 10, figs. 4, 5.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, St. David's.

Phacopidæ.

Phacops Llanvirnensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 187, t. 9, figs. 3, 4.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, St. David's.

Homalonotus, König, 1826.

Homalonotus bisulcatus, Salter.

Pl. 16, figs. 1–8.

H. bisulcatus, Appendix Pal. Foss. Woodw. Mus., Pl. 1 G., figs. 24–31. Monog. Brit. Trilob., 1865, pl. 10, figs. 2–9.

A fine species, highly characteristic of the Caradoc sandstone of Britain, and described rather fully in the works above quoted.

Localities.—Shropshire and Wales, everywhere in CARADOC rocks; but rarely found in LLANDEILO beds.

H. bisulcatus, Salter?

Pl. 11 A., fig. 8.

Although very imperfect, this specimen clearly represents the species above quoted, or at least there is no appreciable difference between crushed specimens of one and the other.

Locality.—ARENIG. Ty-obry, near Garth, Portmadoc, in black slate; also W. of Tremadoc (Prof. Sedgwick's coll., 1857).

Homalonotus rudis, Salter.

Pl. 16, figs. 9–11.

Synopsis, Pal. Foss. Woodw. Mus., pl. 1 E., fig. 20. Monogr. Brit. Trilob., 1865, pl. 10, figs. 12–14.

This also has been pretty fully described, as above. Good specimens of the caudal portion have since been found in the fine yellowish grits of Cressage, Shropshire, the surface of which is finely tubercular, and the axis faintly nodular. These specimens show also that the lower furrows of the tail are as strong as the front one in this species: they are far less conspicuous in the kindred species *H. bisulcatus*. Moreover *H. rudis* is strongly trilobed; while the other follows the general form of the genus, and is related to numerous species of so-called *Trimerus* in the American rocks. *H. Brongniartii*, from the sandstone of May, Normandy, and lately described from S. Devon, is an extreme example of the simpler form of the genus. Its caudal edge is much incurved, and the species, like all other Normandy fossils, is distinct from the British forms.

Localities.—Fig. 11 from the CARADOC or BALA rocks of Shropshire, near Cressage. Figs. 9, 10 from near Bala, N. Wales.

Nesuretus, Hicks, 1873.

Quart. Journ. Geol. Soc., vol. xxix., p. 44. 1873.

This singular genus can hardly be placed in any family, having affinity with three or four; it is related to *Dikelocephalus* through its pygidium, and to *Calymene* and *Homalonotus* through the thoracic segments, and the glabella finds affinity with some forms of the *Conocephalidæ*. The species of the genus are confined to the Tremadoc series of Ramsey Island and Tremanhire, near St. David's. Both places have yielded all the known species. Mr. Hicks has described and figured four species, all of which are confined to the Tremadoc rocks of the St. David's promontory, the N. Welsh localities not having as yet yielded any forms of *Nesuretus*; about 30 species in other groups, 25 of which are new, are associated with this genus in the same beds.

Formation and Locality.—TREMADOC rock. Ramsey Island and Tremaenhir.

N. elongatus, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 45, t. 3, figs. 1–3.

Formation and Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

N. Ramsayensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 44, t. 3, figs. 7–10 and 16–22. 1873.

Formation and Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

N. recurvatus, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 45, t. 3, figs. 5, 6.

Formation and Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

N. quadratus, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 45, t. 3, figs. 11–13 and 23–26.

Formation and Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

Sub-kingdom, CŒLENTERATA.

CLASS, **Hydrozoa.** Huxley.

Order, HYDROIDA, Huxley.

Division, *Graptolithina*, Bronn.

Rhabdophora, Allman.

The *Rhabdophora* or *Graptolites* constitute a very large and important group of fossils; but here we have but few N. Wales species to either notice or describe, yet they cannot be passed over without making a few remarks on a group which is most important as a Silurian index, and is more populous in species and genera than has been hitherto usually believed. The family of *Graptolitidæ* has of late and is now receiving renewed attention. Barrande has given us full descriptions and exact figures. Professor M'Coy first defined many genera, Geinitz endeavoured to systematise the nomenclature, and Professor Hall has given us many new forms. But the discoveries of the latter author, and of the late Sir W. Logan in Canada, Linnarsson in Sweden, with Lapworth, Nicholson, Hopkinson, and Carruthers in Britain, has thrown an entirely new light on the history and extent to which the members of the group vary in complexity and form.

There is a complete gradation of forms, from the simplest up to the most compound, in this remarkable family. But it is probable that the majority of the specimens we see *are* somewhat imperfect. It is evident that in any rock where the remains of a single species are abundant, we should find some in a more or less perfect condition. It is, however, certain that the *Rhabdophora*, occurring as they did in great shoals in muddy deposits, probably in a moderately deep sea, often unaccompanied by any other fossils, and tranquilly laid down upon the soft carbonaceous mud, would be less likely to be broken up than most fossils, and that specimens found in sand or conglomerate would naturally be mere fragments. But such as are invariably imbedded in soft shale would be as little likely to be disturbed or broken as any other kinds of organic remains. They obtain their maximum of development in the rocks, Arenig, Llandeilo, and Llandover rocks, and the Arenig species have their equivalents in Canada and America. They die out at the close of the Silurian period.

Excluding certain genera, such as *Dictyonema* and *Dendrograptus*, &c., the Graptolitidæ may be characterised as possessing a compound polypary consisting of a tubular chitonous investment enclosing the cænosarc, giving origin to numerous cup-like "cellules" or hydrothecæ, each of which contained and protected a polypite. A complete series of forms, from the simple rod with a few cells on one side, to double-forked, branched, cæspitose, and net-like have now received the attention of the above-named naturalists, and rendered the group capable of being systematically treated as

The morphology and affinities of the Rhabdophora have formed the subject of many elaborate essays and papers having reference to their history and distribution through the Silurian rocks of Britain, certain members of which they eminently characterise, especially so the Arenig, Llandeilo, Caradoc, and Llandovery series; their first appearance being in the Shineton shales in Shropshire, we have between 40 and 50 species in the Arenig rocks, the same in the Llandeilo and Caradoc, but few species are common to all three of the formation. The Moffat group in Scotland, so elaborately worked out by Lapworth, seems separable into three divisions, lower, middle, and upper; these can be divided into distinct zones, each characterised by the presence of some well-marked species. Mr. Lapworth finds that the lower Moffat beds contain the Graptolites of the Hudson River group of N. America. The middle Moffat series, according to the same author, may be the equivalent of the Upper Llandeilo beds of Builth, whilst the upper Moffat species are Caradoc.* We have now no doubt about the age of the Arenig Hydrozoa of the St. David's area (Ramsey Island and Whitesand Bay), or those of the Stiper Stone and Shelve area. The Skiddaw slates and Graptolites of Cumberland, as compared with the Shelve beds and their fauna, and also the rocks of St. David's, seem to show a succession of species enabling us to correlate these areas one with the other. It is also singular that most of the Dendroid forms are present in the St. David's beds, and it is only here that this type of the Hydrozoa are abundant in Britain. The stratigraphical value therefore of the Graptolithina as a group is fully tested by their distribution through the Arenig, Llandeilo, and Caradoc rocks of all regions when they occur. The affinities of the Graptolites is yet a matter of opinion, probably they constitute an aberrant and ancient type of the Hydrozoa. They undoubtedly approach the modern Sertularians in many characters (*vide* Nicholson, Manual of Palæontology, vol. 1, p. 165, and Allman on the Morphology and Affinities of the Graptolites, A. M. N. Hist. vol. 9, 4 ser., p. 364, 1872).

The careful researches and generalizations of Linnarsson in Sweden, Lapworth, Nicholson, Hopkinson, and Carruthers in our own country, upon the history, structure, and distribution of the Rhabdophora through the lower Palæozoic rocks of Scandinavia and Britain has added much to our knowledge as to the stratigraphical value of the Graptolites and their correllation generally. The pages of the Quart. Journ. of the Geol. Soc. and the Geol. Mag. are enriched by the careful papers of each of the above authors upon this group of the Cœlenterata, but to none are we so much indebted as to Mr. Lapworth for his exhaustive researches in this field of Palæontology.†

Few groups are more difficult to determine zoologically than the Rhabdophora, but doubtless they are of high stratigraphical value in determining the age of many horizons in the older Palæozoic rocks. Even unaided by stratigraphical succession, when not clear and decisive, they are of reliable value, especially when inversion or faulting has much disturbed either large or small areas. Mr. C. Lapworth's in Britain researches run parallel with those of Barrande in Bohemia and Linnarsson in Sweden (and others needless to mention here). The Scanian rocks of Sweden show a remarkable and clear succession of Palæozoic deposits; 3 Graptolite schistose beds occurring amongst 12 recognised divisions, stages, or zones. These 3 Graptolite zones Linnarsson terms Lower Graptolite or Phyllograptus schists, Middle Graptolite or Dicranograptus schists, and Upper Graptolite or Monograptus schists. The former Linnarsson believes may be correlated with our Arenig beds, the Quebec group of Canada. The second probably with the lower part of the Llandeilo and Upper Arenig. The third or upper may be identified or parallelled with the Berkhill shales of Scotland. In Scotland the *Monograptidæ* first appear in the Upper Moffat group or Birkhill shales; they are wanting below in the Middle and Lower Moffat beds. The numerous forms occurring in the Birkhill shales afford data for correlation with other "similar deposits in the N. of England, Ireland, Thuringia, Bohemia, and "Scandinavia." These researches throw much light upon the history and distribution of the Rhabdophora through the same horizons in Britain. They

* *Vide* Ann. Mag. Nat. Hist., Ser. V.S., Vol. III.
† *Vide* Lapworth Quart. Journ. Geol. Soc. vol. 34, pp. 240-347, also Geol. Mag. in volumes 3 & 4 Dec. II. and passim.

enable us to elevate this group through its genera and species into exponents of definite and restricted formations, and as such of equal value zoologically with the Brachiopoda, Cephalpoda, and Echinodermata. We may with Lapworth fully believe that the "Graptolites are destined to play "among the Lower Palæozoics, the part filled by the Ammonites among "the Jurassic rocks in fixing the minor divisions of the deeper water beds, "and in determining their parallelism in areas now geographically separated."

The range of the Rhabdophora extends from the Lower Arenig or base of the Skiddaw slates to the highest beds of the Ludlow group. It would also appear that the genera Dichograptus, Tetragraptus, and Phyllograptus are restricted to the Arenigs (Lower Ordovicean of Lapworth) as pointed out by Nicholson. Climacograptus and Diplograptus are Arenig, Llandeilo, and Caradoc genera, and Rastrites and Cyrptograptus range no higher than the Caradoc.

Again we find, on careful analysis of the labours of Nicholson, that the rocks of the Skiddaw or Arenig period contains *Trigonograptus*, *Climacograptus*, *Diplograptus*, and *Didymograptus*. His second period, the Llandeilo and Caradoc, contain the genera *Diplograptus*, *Didymograptus*, *Climacograptus*, *Dicranograptus*, *Cœnograptus*, *Pleurograptus*, *Cyrtograptus*, *Rastrites*, and *Retiolites*. Dr. Nicholson's generalizations are fully borne out through the subsequent researches of Lapworth in Scotland and elsewhere.

The Graptolithic fauna of Sweden may be correlated with that of Britain. Linnarsson arranges or places the Graptolite bearing beds in or under four of the five groups that are recognised in the Scandinavian stratified rocks.

Group 1. The Upper Graptolite schists which appear to be upon the horizon of our Coniston mudstones, or Skelgill beds and Gala series, and in which the unbranched Monoprionidian forms are abundant, and, as in our series, the branched forms *Didymograptus* and *Climacograptus* are absent. Many species are common to one area. In Sweden and Bohemia, five, *Monograptus priodon*, *M. lobiferus*, *M. colonus*, *Rastrites peregrinus*, and *Retiolites Geinitzianus*.

Group 2. The Middle Graptolite schists of Norway are without doubt the equivalents of the Moffat series of the S. of Scotland or the Lower Moffat shales of Lapworth. *Climacograptus teretiusculus*, *Didymograptus gemnius*, *Dicellograptus*, and *Dicranograptus* characterise the beds in both countries; no Monograpti appear here.

Group 3. The Lower Graptolite schists of Sweden represents the Skiddaw or Arenig series of Britain,—*the Quebec Group of Canada*,—but the English beds yield a far richer fauna than the Swedish, *Phyllograptus*, *Didymograptus*, *Tetragraptus*, *Dichograptus*, *Climacograptus* are common to both countries. *Pleurograptus* may occur in Sweden. *Glossograptus*, *Thamnograptus*, *Dicellograptus*, *Trichograptus*, *Temnograptus*, *Schizograptus*, *Clematograptus*, and others appear as yet to be confined to Britain.

The fourth or Olenus and Dictyonema schists of Ostrogothia and Scania may possibly equal in time our Dictyonema series at Malvern, or the Tremadoc beds of Ramsey Island, St. David's, where Hopkinson discovered and named several species of these dendroid or netted forms.

The value of the Graptolites as stratigraphical indices or guides is quite equal to that of the Trilobita. Nicholson, Linnarsson, Lapworth, Hopkinson, and others have long shown the uniform manner in which the Rhabdophora have been distributed both in space and time.

R.E.

Monograptus (*Graptolithus*) *sagittarius*, Linn.

Pl. 11 A., fig. 2.

Climacograptus, Hall.

C. cælatus, Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 655, t. 35, fig. 8.

Formation and Locality.—Lower Llandeilo. Abereiddy Bay.

C. confertus, Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 655, t. 34, fig. 4.

Formation and Locality.—Upper Arenig. Porth Hayog, Ramsey Island.

Climacograptus (*Diplograptus*) *bicornis*, Hall.

(Pl. 11 A., fig. 1, *b. c.*)

Hall, Pal. New York, vol. i., pl. 73, fig. 2.

There is no tangible character to distinguish this (when the forked base is absent) from *C. teretiusculus* of Hisinger. It is, however, of a different aspect, for the cells, which are square (not pointed) are only half the distance apart, as in *C. teretiusculus*, and the whole frond is smaller. We have never seen any above an inch in length (Hall figures it nearly double this length), while *C. teretiusculus* has often rods three or four inches long.

Localities.—LLANDEILO, Clarbeston, Haverfordwest; ARENIG? slopes above Tyddyn dicwm, near Penmorfa; Ty-obry. We have only the lateral view.

Climacograptus? (*Diplograptus*) *teretiusculus?* Hisinger.

Pl. 11 A., fig. 3.

Hisinger, Leth. Suec., t. 38, fig. 4; Schärenberg über Graptoliten, t. 2, figs. 17–32.

This fine and very common *Graptolite* is a characteristic Arenig species, never occurring below or rising above the Llandeilo rocks. Synonyms and reference are given to figures above, believing these truly represent the fossil. I might have quoted others less characteristic, and believe *D. rectangularis*, M'Coy, to be the same species.

Locality.—ARENIG; Ty-obry. Llandeilo Flags; Mona Mine, Anglesea; Llanerchymedd, &c.

Dicranograptus ramosus, Hall.

Pl. 11 A., fig. 1, 1 *a.*

Hall, Pal. N. York, vol. i., pl. 73, fig. 3.

We have nothing to add to Professor Hall's description of this species, which, with other well-known Arenig graptolites, are confined in their range to that formation. The Arenig has all the shells, and nearly all its trilobites distinct, and the graptolites are distinct from those of the Llandeilo, or nearly so.

Locality.—ARENIG. Ty-obry, near Garth, Portmadoc.

Diplograptus, M'Coy, 1850.

Diplograptus barbatulus, Salt.

Pl. 11 A., fig. 1.

D. foliaceus, angustus, cellulis obliquis rectis prominulis, quam latitudine axis longioribus oribus transversis, sese spatium cellulæ remotis.

Though unwilling to name a single new species this does not sufficiently agree with any described ones. Professor Hall has figured so many forms under the name of *Graptolithus pristis*, that it is impossible to say ours may not be identical with that figured in his plate 72, fig. 1 *e* or 1 *g*; but if the form we are in the habit of ascribing to the *G. pristis* of Hisinger be the true original species, this Lower Llandeilo fossil must receive a separate name, as the frond is much narrower, and the cells less crowded and less prominent. Hisinger's figure is more like our specimen, but has the cells too prominent and too little oblique to answer to it; on the whole it is safer to give a new name.

The true *D. pristis* is the Caradoc or Llandovery species known under that name in Ireland, Shropshire, and South of Scotland. The Llandeilo flag species is nearer to *D. secalinus*, Hall; and this Lower Llandeilo form appears to be distinct from both.

Locality.—ARENIG. Ty-obry, Garth, opposite Portmadoc. (Mus. Pract. Geol.)

Diplograptus mucronatus, Hall.

Pl. 12, fig. 1; pl. 11 A., fig. 6.

Hall, Pal. New York, vol i., pl. 73, fig. 1.

Though but a small specimen, we must at present identify this with the species figured by Professor Hall. The peculiar shape of the cells, projecting outwards almost as much as their length, and their upper and lower edges so

equal and alike, that it is difficult to tell the anterior from the posterior margin, easily characterise the species, and the long spine to the mouth completes the bizarre appearance of the species.

Locality.—ARENIG. Above Tyddyn Dicwm, Ty-obry, Garth, Portmadoc (pl. 11).

D. dentatus, Brong.

Fucoides, Hist. Véget. Foss., t. 6, figs. 9–12; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 656, t. 34, fig. 5.

Formation and Locality.—UPPER ARENIG. Porth Hayog, Ramsey Island, and Llanvirn Quarry, St. Davids.

D. foliaceus? Murch.

Grapto. Sil. Syst., t. 26, fig. 3; *Diplograp.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 656, t. 35, fig. 7.

Formation and Locality.—LOWER AND MIDDLE LLANDEILO. Abereiddy Bay.

D. tricornis, Carruthers.

Trans. Roy. Phys. Soc. Edinb., p. 468, fig. 2; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 658, t. 35, fig. 6.

Formation and Locality.—LOWER AND MIDDLE LLANDEILO. Abereiddy Bay.

Didymograptus, M'Coy.

Didymograptus geminus? Hisinger.

Pl. 11 B., fig. 8.

Hisinger, Lethæa Suecica, pl. 38, fig. 3 (not of Siluria, 2nd ed., p. 50, Foss. 8).

The true species, with branches running parallel or sub-parallel, is found in the dark grey micaceous Arenig slates, and with it, strangely enough, the following common species, which always seems to accompany it, both in Sweden and Britain.

Locality.—ARENIG. Cefn Gwynlle; Shelve, Shropshire.

(The Swedish form is from the Lower Graptolite schists of Aher.)

Didymograptus hirundo, Salter.

D. geminus, Siluria, 3rd ed., Foss. 8, fig. 8 (not of Hisinger).

D. triuncialis et ultra, bipennis, ramis binis, usque ad angulum 180° *reflexis rectis. Rami ad bases angusti, dein latiores, cellulis approximatis, apicibus recurvis, serratis.*

Although this fossil differs in some respects from a commou Swedish species, we do not hesitate to identify it at present, only premising that, if better specimens should turn up, the English form must retain the name; while the cognate appellation of the variety (*D. Cypsellus**) may serve as a specific designation of the Swedish form. It is not unfrequently labelled *D. geminus* in collections.

The British fossil, commencing with a minute radicle, opens at once to an angle of 180°; instead of curving downwards for a very short distance, and then running straight outwards. But though this is the case with most of the Swedish specimens, a few have the character of the English form. The species appears to have grown to a great length, both in the Swedish and the British varieties. *D. geminus* is a totally different fossil.

The Swedish fossils come from the Lower Graptolite schists (Lower Osla group, Kjerulf) of Aher, which may have to be identified with our true Lower Llandeilo.

Locality.—ARENIG. W. of the Stiper Stones.

* The Latin name for the swift (*Hirundo apus*, Linn.)

Didymograptus, M'Coy, 1851.

D. extensus, Hall.

Grapto., Quebec Group, p. 80, t. 2, figs. 11–16; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 642, t. 33, fig. 1.

Formation and Locality.—Lower Arenig. Road Uchaf, Ramsey Island.

D. sparsus, Hop. and Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 643, t. 33, fig. 2.

Formation and Locality.—Lower Arenig. Road Uchaf, Ramsey Island.

D. pennatulus, Hall.

Grapto., Quebec Group, p. 82, t. 3, figs. 1–8, t. 5, fig. 9; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 643, t. 33, fig. 3.

Formation and Locality.—Lower Arenig. Road Uchaf, Ramsey Island.

D. patulus, Hall.

Grapto., Quebec Group, p. 71, t. 1, figs. 10–15; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 644, t, 33, fig. 4.

Formation and Locality.—Middle Arenig. Whitesand Bay. Upper Arenig. Llanvirn Quarry, and Porth Hayog, Ramsey Island.

D. Nicholsoni, Hop. and Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 644, t. 33, fig. 5.

Formation and Locality.—Upper Arenig. Llanvirn Quarry.

D. affinis, Nich.

Ann. Mag. Nat. Hist. ser. 4, vol. iv., p. 240, t. 11, fig. 20; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 645, t. 33, fig. 6.

Formation and Locality.—Upper Arenig. Porth Hayog, Ramsey Island.

D. euodus, Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 645, t. 35, fig. 1.

Formation and Locality.—Lower Llandeilo. Abereiddy Bay.

D. bifidus, Hall.

Grapto., Quebec Group, p. 73, t. 1, figs. 16–18, t. 3, figs. 9, 10; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 646, t. 33, fig. 8.

Formation and Locality.—Upper Arenig. Porth Hayog, Ramsey Island.

D. indentus, Hall.

Grapto., Quebec Group, p. 74, t. 1, fig. 20; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 647, t. 33, fig. 7.

Formation and Locality.—Upper Arenig. Porth Hayog, Ramsey Island.

D. indentus var. *nanus*, Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 647, t. 33, fig. 7, t. 35, fig. 4.

Formation and Locality.—Upper Arenig, Llanvirn Quarry; and Lower and Middle Llandeilo, Abereiddy Bay.

D. Murchisoni, Beck.

Grapto., Murch., Sil. Syst. t. 26, fig. 4; *Didymo.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 648, t. 35, fig. 2.

Formation and Locality.—Lower Llandeilo. Abereiddy Bay.

D. furcillatus, Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 649, t. 35, fig. 3.

Formation and Locality. LOWER LLANDEILO. Abereiddy Bay.

Dendrograptus, Hall, 1862.

Dendrograptus furcatula, Salt.

Pl. 11 A., fig. 5.

Not above an inch high, slender, repeatedly dichotomous at a small angle, and beset with numerous conical cells with simple mouths (and no spines) on a slender rhachis.

A small bushy species, of which the above is nearly all that can be said. As to structure, it is little more than a film on the surface of the iron-stained slate; but the simple shape of the cells can be made out, and they are very like those of ordinary *Graptolithus*, such as *G. Nilssonni* or *G. tenuis*. They are still more like the figures of branched *Graptolites* given by Hall. The genus *Thamnograptus* of Hall can hardly be distinguished from *Dendrograptus*.

See report of progress for 1857 of Geol. Surv. of Canada. 1858.

Locality.—ARENIG. Ty-obry, Penrhyn.

D. flexuosus, Hall.

Grapto., Quebec Group, p. 127, t. 17, figs, 1, 2; *Dendro*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 662, t. 36, fig. 3.

Formation and Locality.—LOWER ARENIG. Road Uchaf, Ramsey Island. MIDDLE ARENIG. Whitesand Bay, St. David's.

D. persculptus, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 663, t. 36, fig. 4.

Formation and Locality.—LOWER ARENIG. Whitesand Bay, St. David's.

D. arbuscula, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 663, t. 35, fig. 5.

Formation and Locality.—LOWER ARENIG. Road Uchaf, Ramsey Island, and Whitesand Bay. MIDDLE ARENIG. Whitesand Bay.

D. diffusus, Hall.

Grapto., Quebec Group, p. 132, t. 18, figs. 1–3; *Dendro*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 664, t. 36, fig. 7.

Formation and Locality.—LOWER ARENIG. Road Uchaf, Ramsey Island.

D. Ramsayi, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 664, t. 36, fig. 2.

Formation and Locality.—LOWER LLANDEILO. Abereiddy Bay.

D. serpens, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 665, t. 37, fig. 3.

Formation and Locality.—LOWER LLANDEILO. Abereiddy Bay.

Tetragraptus, Salter, 1862.

T. quadribrachiatus, Hall.

Grapto., Quebec Group, p. 91, t. 5, figs. 1–5, t. 6, fig. 5, 6; *Tetrag.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 649, t. 33, fig. 9.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay, St. David's.

T. serra, Brong.

Fucoides, Hist. Véget. Foss., vol. i., p. 71, t. 6, fig. 7, 8; *Tetragrap.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 650, t. 33, fig. 10.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay, St. David's.

T. Halli, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 651, t. 33, f. 11.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay.

T. Hicksii, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 651, t. 33, fig. 12.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay, St. David's.

Clematograptus, Hopkinson, 1875.

C. implicatus, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 652, t. 34, fig. 1.

Formation and Locality.—MIDDLE ARENIG. Whitesand Bay, St. David's.

Nemagraptus, Emmons, 1855.

N. capillaris, Emmons.

American Geology, vol. i., t. 1, fig. 7; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 653, t. 34, fig. 2.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, St. David's.

Dicellograptus, Hopkinson, 1870.

D. Moffatensis, Carruthers.

Trans. Roy. Phys. Soc. Edinb., p. 469, fig. 3; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 654, t. 34, fig. 3, t. 35, fig. 5.

Formation and Locality.—UPPER ARENIG, Llanvirn Quarry; and MIDDLE LLANDEILO, Abereiddy Bay.

Phyllograptus, Hall, 1858.

P. stella, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 658, t. 34, fig. 6.

Formation and Locality.—LOWER ARENIG. Road Uchaf, Ramsey Island.

Glossograptus, Emmons, 1855.

G. ciliatus, Emmons.

American Geology, vol. i., p. 108, t. 1, fig. 25; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 659, t. 34, fig. 7.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry.

Trigonograptus, Nicholson, 1869.

T. ensiformis, Hall.

Retiolites ensiformis grapto, Quebec Group, p. 114, t. 14, figs. 1–5; *Trigonograptus*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 659, t. 34, fig. 8.

Formation and Locality.—LOWER ARENIG. Road Uchaf, Ramsey Island.

T. truncatus, Lap.

Quart. Journ. Geol. Soc., vol. xxxi., p. 660, t. 34, fig. 9.

Formation and Locality.—Road Uchaf, Ramsey Island.

Ptilograptus, Hall, 1865.

P. cristula, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 661, t. 36, fig. 2.

Formation and Locality.—LOWER ARENIG. Road Uchaf, Ramsey Island.

P. Hicksii, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 661, t. 36, fig. 1.

Formation and Locality.—Lower Arenig. Road Uchaf, Ramsey Island.

P. acutus, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 662, t. 37. fig. 1.

Formation and Locality.—Lower Llandeilo. Abereiddy Bay.

Callograptus, Hall, 1865.

C. radiatus, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 665, t. 36, fig. 8.

Formation and Locality.—Lower Arenig. Whitesand Bay and Road Uchaf, Ramsey Island.

C. radicans, Hop.

Ann. Mag. Nat. Hist., 4 ser., vol. x., p. 233, t. 10; *ib.*, Quart. Journ. Geol. vol. xxxi., p. 666.

Formation and Locality.—Lower Arenig. Road Uchaf, Ramsey Island.

C. Salteri, Hall.

Grapto., Quebec Group, p. 135, t. 19, figs. 5–8; *ib.*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 667, t. 36, fig. 10.

Formation and Locality.—Middle Arenig. Whitesand Bay, St. David's.

Dictyograptus, Hall.

Dictyonema, Hall, 1852.

D. cancellatus, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 668, t. 36, fig. 11.

Formation and Locality.—Lower Arenig. Whitesand Bay, St. David's.

D. irregularis, Hall.

Dictyonema, Quebec Group, p. 136, t. 20, figs. 1, 2; *Dictyograptus*, Hop. and Lap., Quart. Journ. Geol. Soc., vol. xxxi., p. 668, t. 36, fig. 12.

Formation and Locality.—Middle Arenig. Whitesand Bay, St. David's.

D. Homfrayi, Hop.

Quart. Journ. Geol. Soc., vol. xxxi., p. 668, t. 36, fig. 13.

Formation and Locality.—Lower Arenig. Road Uchaf, Ramsey Island.

R.E.

Dictyonema.

Hall, Pal. New York, vol. 2, p. 174.

General character a rooted cup-shaped frond, of long, parallel, dichotomous branches connected by very irregular placed processes (dissepiments). The branches of corneous texture (without a fibrous layer), with a double row of cells (which have projecting angular mouths) on the inner sides of the frond.

Dictyonema sociale (Salter).

D. venustum, Lapw.

Pl. 4, fig. 1.

Ref. Siluria, 2nd ed., Appendix, pp. 541, 562; *Graptopora*, p. 47, foss. 7, fig. 3.

D. triunciale, frondibus tubulosis congregatis, 3–4 ex eâdem radice tenui; ramulis parallelis approximatis; dissepimentis crebris.

The English species may not prove identical with the larger Scandinavian form (*Gorgonia flabelliformis*, Eichw.), therefore we give a separate s character. But the two appear to me, except in size and in the regula the meshes, to differ in no important particular. M. Kjerulf, in a co lately sent from Norway, included specimens of the Scandinavian f

Fenestella socialis, under which name the English species had been for some time in our cabinet. It was not until 1857 that Mr. Salter discovered the generic character in the projecting denticles of the inner surface of the ramuli: which character had also escaped Professor Hall, in characterising the genus from American Upper Silurian specimens (Pal. New York, vol. ii., 1852, pl. 40 F, fig. 1). A description of the genus *Graptopora* was read before the American Association of Science, 1857.

The fronds are frequently 3 inches long and 1½ broad at the top, cup-shaped, and pretty regularly conical. They are very generally grouped in threes or fours at the base, and must have grown obliquely, if not horizontally, as they now appear upon the slabs. The attachment (fig. 1 *a*) is a short radicle, which soon branches into three or four dichotomising stems, and these again branch three or four times in the lower and middle part of the frond, till the full number of 30–35 parallel stems (or interstices, as they used to be called) are obtained, which end rather abruptly and regularly at the upper margin.

The branches themselves are minutely flexuous throughout, and throw off on either side thin processes (or dissepiments), very irregular in direction and position, sometimes oblique upwards, sometimes downwards, and not unfrequently two close together or partially coalescing (fig. 1 *c* at †). The cells are visible even on the back of the frond as a double row on the branches, projecting a little on each side of them; they are rather closely set, and about the diameter of the branches apart.

The mouth of the cells only show on parts of the English specimens (fig. 1 *c* at *), but are clearly seen in those from Scandinavia, along the whole length of those branches which are laterally compressed.

They are projecting angular processes, exactly like the teeth of *Graptolites*, the lower edge oblique, and produced upwards into a short spine, the upper edge nearly straight and horizontal, or a very little concave. They are not unlike the cell mouths of *Didymograptus geminus*, a species of *Graptolite* which occurs with Eichwald's *Dictyonema* in the lowest alum slates of Scandinavia.

The irregularity of the dissepiments is a character not very rare in *Fenestella*. The projecting corneous cells separates *Dictyonema* from the *Fenestellidæ*, and probably constitutes it a connecting link between that family and the *Graptolithina*.

The *Fenestellidæ* are recognised as an extinct group of *Bryozoa* allied to *Retepora*, and differing from it chiefly by the presence of a vertical fibrous layer on the reverse side. But all the known species are calcareous, furnished with the fibrous layer above noted, on which are set short cells quite distinct from each other; so that to convert a *Fenestella* into a *Graptolite*, even supposing we have the least branched species of the former, and the most complete of the latter to compare, it would be necessary to get rid of nearly all the calcareous material, reduce the skeleton to a mere thread (the axis), and lengthen out the cells enormously, while they were made fully to communicate with each other at their bases. The connecting processes too (or dissepiments) of *Fenestella* must be removed, as nothing of the kind has yet been observed in the *Graptolithina* other than the present genus.

Gorgonia flabelliformis is abundant in the lower schists of Russia as well as Sweden, Angelin proposed the name *Phyllograpsus* in MSS. for it (Siluria, 2nd ed., p. 369, note). It is evident, therefore, that the Swedish palæontologist has observed the affinity above noted. Mr. Salter would have adopted his unpublished name, were it not that Professor Hall feels convinced* of the identity of this primordial genus with his Upper Silurian *Dictyonema*: were there, however, any doubt of the identity of the two genera, the name *Graptopora* would be more in unison with those of other genera of the *Fenestellidæ*, and at the same time indicate a true relation with the *Graptolite* group.

Locality.—Uppermost Lingula Flags.—In black slate at Bron Foel slate quarries, S.W. of Tremadoc,—abundant. In beds in the railway above Plas Oakley, Maentwrog,—rare. Brampton Bryan Park, Pedwardine, Shropshire; Keys End Hill, Malvern.

* In letters received from Professor Hall; also in his contribution to the reports of the Geol. Surv. of Canada, Rep. Progress, 1859, p. 142, where the genus is described, and the affinities of the *Graptolites* with *Bryozoa* discussed, p. 144.

D. delicatulum, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 172, t. 7, f. 1.

Formation and Locality.—LLANDOVERY. Bryn-y-Carnau, Aberystwyth.

D. corrugatellum, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 172, t. 7, f. 3.

Horizon and Locality.—LLANDOVERY. Devil's Bridge, Aberystwyth.

D. venustum, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 171, t. 7, f. 1.

Locality.—Devil's Bridge, Aberystwyth.

Genus Calyptograptus, Spencer, 1878–9.

C. plumosus, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 173, t. 7, f. 4.

Horizon and Locality.—LLANDOVERY. Devil's Bridge, Aberystwyth.

C. digitatus, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 174, t. 7, f. 6.

Horizon and Locality.—LLANDOVERY. Devil's Bridge, Aberystwyth.

Genus Acanthograptus, Spencer, 1878–9.

A. ramosus, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 174, t. 7, f. 5.

Horizon and Locality.—LLANDOVERY. Devil's Bridge, Aberystwyth.

Genus Odontocaulis, Lapw., 1881.

O. Keepingii, Lapw.

Quart. Journ. Geol. Soc., vol. xxxvii., p. 176, t. 7, f. 7.

Horizon and Locality.—LLANDOVERY. Devil's Bridge, Aberystwyth.

Brachiopoda.

LINGULIDÆ.

Lingulella, S. Woodward, 1861.

Nearly equivalve, broad oblong, the ventral valve pointed and with a distinct pedicle groove. Muscular scars strong, nearly as in *Obolus*, but the pair of anterior retractors (C.) are more linear, and the sliding muscles (B.) small, and not quite so external as in *Obolus*.

The form, as well as what we know of the interior, is more like *Lingula* than *Obolus;* but the arrangement of the muscles in the only valve of which we possess the interior (ventral?) is more like the figures of *Obolus*. The anterior retractors diverge widely and are linear, the central (protractors?) come nearly down to them. And the external (or sliding) muscles are too small and too near the centre for *Obolus*.

The descriptions of *Obolella*, Billings, Geol. Surv. Repts. Canada, 1861, 1862, recalls this, but his later figures show a very different set of muscular scars.

L. Davisii, M'Coy.

Pl. 2, fig. 7–12; Pl. 4, fig. 14.

SYN.—*Lingula*, Davis, Quart. Geol. Journ., vol. ii., p. 71; The Tremadoc *Lingula*, Sedgwick, ib., vol. iii., pp. 140, 143, 147; *L. Davisii*, M'Coy, Synopsis Woodw. Mus., pl. 1 L, fig. 7 (also when distorted as *Tellinomya lingulæcomes*, id., pl. 1 K, fig. 18; Siluria, 2nd ed., 1859, Foss. 4, fig. 1, p. 45, &c.; *Lingulella Davisii*, Mono. Brit. Sil. Brach. Pal. Soc., p. 56, t. 4, f. 1–16.

L. fere uncialis, lata, depressa, subplana, nisi ad apicem acutum paullulum conveza. Superficies regulariter striata, striis concentricis.

This, the commonest of all "Lingula flag" fossils, has been already well described as to its exterior by Professor M'Coy, and figured in the work above quoted. The specimens were brought to Cambridge by Professor Sedgwick, when he first assigned their true place to the Lingula flags in 1846, as the *Ffestiniog* group.

The very wide, depressed, and somewhat pentagonal form (satchel-shaped, M'Coy), the obtusely pointed beak, the straight edges meeting there at an angle of about 100°, and the irregular fine ridges of growth, have all been described accurately by Professor M'Coy. The interior presents everywhere traces of the points of connexion with the mantle, both on the margin and on the ovarian region (pl. 4). The muscular impressions are seen very rarely, but, as above described, we have them in one specimen. The hinge area (in the more pointed valve at least, for we cannot be sure of it in the other) is flat, rather broad and striated: the groove for the pedicle is linear and well pronounced. The surface is remarkably even and regular, the median area not raised at all, nor distinctly striated, nor in any way separated from the general surface. The lines of growth are remarkably sharp and distinct, but yet are not regular striæ. Nor can we in the *most cases* detect any longitudinal lines. They sometimes occur over the anterior portion, pl. 1, fig. 11.

Localities.—Everywhere in the middle portion of the LINGULA FLAGS; rare in the lowest and highest portion, but of nearly full size again in the sandy beds of the UPPER TREMADOC slate. Specimens nearly always more or less distorted; and in that state have been referred to *Tellinomya*.

Lingulella ferruginea, Salt. Quart. Journ. Geol. Soc., vol. xxiii., p. 339, fig. 1, 1867.

This species from the black flags of the Menevian group at Pen-y-pleidian St. David's, and its variety. *Ovalis* from the red slaty rocks of the Menevians, are the oldest known forms of the *Lingulidæ*.

Lingulella primæva, Hicks. Quart. Journ. Geol. Soc., vol. xxvii., p. 401, t. 16, figs. 13–14, 1871.

This is a larger shell than *L. ferruginea*, and both species occur in the same red beds at the base of the purple sandstones at Caer-fai, Nun's Hill, and Porthclais Harbour, S. of St. David's.

Lingulella lepis, n. sp.

Fig. 11.

Lower Tremadoc, Borth woods, Portmadoc.

L. minor, vix semiuncialis, quam L. Davisii rotundior, ovata, apice acuto Impressiones musculares centrales profundi, paullo divergentes.

A smaller shell than *L. Davisii*, rarely occurring in the higher beds of the Lingula flags, but common throughout the Lower Tremadoc, and ranging also into its upper beds.

It is broad ovate, the beak short pointed, the form convex; the surface concentrically and sharply striate, with rather distant antiquated ridges of growth. Interiorly the pedicle has a short broad groove, and the central protractor muscles fill a narrow angular space, and are strongly bordered on each side. In *Obolella* they diverge widely, according to Mr. Billings' figures, and we have also a small species from the Upper Lingula flag (black shales) of Malvern?

Locality.—[LOWER and UPPER LINGULA FLAGS of the Portmadoc district.] LOWER TREMADOC slate, everywhere in the Tremadoc district, and also near Tai-hirion, Arenig. UPPER TREMADOC, Moel-y-gest, north side, and Garth, opposite Portmadoc.

Lingulella, sp.

Lingulella Davisii has been quoted from Marchlyn-mawr, Llanberis, Reports Brit. Assoc., Belfast, l.c., but the species appears distinct, and not perfect enough to describe.

Locality.—Lower Lingula Flags. Marchllyn-mawr, N. of Llanberis.

Obolella, Billings, Canadian Reports, 1861–2.

Section *Monobolina*, muscular scars united closely along the central line.

Obolella plumbea, Salter.

Pl. 11B, fig. 10.

Lingula plumbea, Salter. Siluria, 2nd ed., 1859, foss. 8, fig. 1.

O. magna (*magn. O. cingulatæ*, Bill.) *latè trigona, ad frontem valde rotundata, ad apicem obtusa, lateribus superioribus* rectis seu excavatis. Superficies glabra, lineis concentricis rugulosa, radiisque creberrimis ornata.*

A remarkably broad species, the breadth exceeding the length in the proportion of 4 to 3, with a pointed beak, slightly hollow upper margin, and broadly rounded below. The appearance is roughly pentagonal, but all the lower angles being so much rounded, it is not right to call it a pentagon in any sense. The surface is polished, but marked with many concentric rings of growth, and strongly radiated from the convex beak to the front margin. The muscular scars are remarkably strong and closely defined, and are less divided or bilobed than even in *O. pretiosa*, Billings, in which species this undivided character is most conspicuous.

It is probable we have not yet exhausted all the genera of the *Lingulidæ* from the very oldest rocks. And *O. plumbea* will likely enough in future form the type of a new genus, distinguished particularly by this union of the muscular scars. The sectional name indicates this.

Locality.—Arenig. W. of the Stiper Stones, abundant.

Obolella, sp.

Pl. 12, fig. 7.

Our figure represents this small fossil as rather too pointed. It was at one time referred to *Lingula attenuata*, Sow., but it is clearly distinct, and probably belongs to the above genus.

Locality.—Arenig. Llanfaelrhys, S. Caernarvonshire (with *Ogygia Selwynii* and *Graptolites sagittarius*).

Obolella, sp.

Pl. 12, fig. 8.

A more decided species of the genus than the last. It shows the central muscular impressions well, and has the rounded form usual in the genus. It is not intended to name these fragmentary species.

Locality.—With the last.

Dinobolus, Hall, 1871.

Dinobolus? Hicksii, Dav. Quart. Journ. Geol. Soc., vol. xxxi., p. 188, t. 10, f. 6.

This is the only species of *Dinobalus* known in Britain, but four have been recognised by Hall and Billings in America. Mr. Salter named in MS. a species of *Obolus* (*O. transversus*), a shell somewhat abundant in the Wenlock rocks, and which *D. Hicksii* strongly resembles, and it is doubtful if the genus is not the same. Hall's specimens, however, favour the idea that the older form is different.

Formation and Locality.—Upper Arenig. Llanvirn quarry.

* I cannot adopt the term "posterior," as it must be so generally misunderstood.

ORTHIDÆ.

Orthis, Dalm., 1827.

O. calligramma, Dalm.

Pl. 22.

DIAGNOSIS.—*O. semiovalis seu subquadrata, cardine longiori. Valvæ duæ lentè convexæ. Costæ simplices, interlineatæ aut numerosissimæ, virgulatæ; striis transversis, sæpe longitudinalibus, ornatæ. Processus cardinalis angustissimus linearis.*

Referring to the Memoirs of the Survey* for details connected with the several varieties of *Orthis calligramma* therein described but not figured, we will here only give the characters of the principal varieties from the Lower and Middle Silurian rocks of Wales. The species is a common one, and characteristic of the lower series. It has been so used repeatedly by Sir R. I. Murchison and other authors.

[The kindred British species also with large ribs, *O. Actoniæ* and *O. flabellulum*, are figured on the preceding plate by Mr. Bone, and are faithful portraits.]

From these two species it is readily distinguished by having both valves slightly convex; on the other hand the ventral valve is flat in *O. flabellulum*, the dorsal flat or concave in *O. Actoniæ*. But there is also a constant difference in the internal characters. The central tooth or cardinal process† is quite narrow-linear, and reaches from the beak as far back as the bases of the hinge teeth (or socket walls as Professor King terms them). These teeth diverge very regularly at an angle of about 80° or 90°, rarely less; and are narrow plates, a little thickened outwards, and leaving a subulate hollow between them and the hinge margin. In the cast, the interval between these bifid teeth filled up with matrix, presents a short broad pyramid, flanked by the subulate projections from the cavities under the hinge. The following are the variations of the surface.

In all the typical varieties, the ribs, instead of being angular as in *O. Actoniæ*, or simple undulations as in *O. flabellulum*, are raised squarish ridges, with an equal interval between them; both ribs and furrows being crossed by close transverse lines, and often longitudinally striated.

In the beautiful figures by De Verneuil (Geol. Russia, vol. ii.), and in Irish specimens from Galway in our cabinet, this character is well shown. The length of the hinge line varies much even in those varieties which have the thick broad ribs, in the type *O. calligramma* it is much shorter than the width of the shell; in the var. *Orthambonites* De Verneuil figures some with a very broad hinge line greatly exceeding the general width of the shell, and he has also shown great variations in the number of ribs, from 14 or 16 to twice that number.

O. calligramma, var. *proava*, Salter probably *O. Carausii* Salt.

Pl. 22, fig. 1.

Our Llandeilo type, fig. 1, agrees best with the squarer varieties of *O. calligramma* proper, and has the longitudinal striæ as well as the transverse ones. Otherwise Mr. Salter was disposed to refer it to the variety *Orthambonites* of De Verneuil, whose description at least allows us to recognise two well marked races or sub-species, viz., those with and those without the longitudinal lines.

In form this variety comes nearest to Pander's *O. tetragona*, but that shell has at least 20 moderate-sized equal ribs. It may be distinguished as a variety, recognisable by its convex shape and square form, with a hinge line equal to the shell in width, a convex dorsal valve rather deeply lobed, and with 14 strong ribs longitudinally striate, the middle ones remote, the outer ones interlined and smaller. The internal septum is short and strong,—the hinge teeth somewhat stouter than usaul. Specimens lately found by Professor Hughes in the gritty beds near Llanerchymedd tend to show that Orthis

* Vol. ii., part 1, p. 374.

† Davidson, Introduct. Brachiopoda, 1853, speaks of this as simple. It is always so in *Orthis* proper.

carausii occurs there, this species is associated with *Nesuretus*, a characteristic trilobite in the Tremadoc beds of St. David's, other conditions lead me to believe that those beds at Llanerchymedd are of Tremadoc age. R. E.

Locality.—TREMADOC (or LLANDEILO) rocks, in grits among the black slates of Llanerchymedd, Anglesea.

Var. *Calliptycha*, M'Coy (var. *plana*, Pander).

Pl. 22, fig. 2.

M'Coy describes his shell as a beautiful variety, differing chiefly from the ordinary form in the strength of the intermediate striæ. It has much the same form and proportions as the flatter valve of *O. plana*, Pander, and as M'Coy describes his variety (*Calliptycha*, Pal. Foss. Woodw. Mus., p. 215) as having only 18 instead of 24 ribs, Mr. Salter referred it to the foreign type. *O. ovata*, Pander, is a much more convex and elongate form. The hinge line is shorter than the width of the shell; the dorsal valve flat, the area broad-triangular, the ribs square, and the interspaces strongly ribbed lengthwise. The ribs themselves show nothing but the transverse squamæ. This is the more common state, even in the extreme varieties next to be described.

Locality.—CARADOC slates of Pembrokeshire.

Var. *virgata*, Sowerby.

Pl. 22, fig. 3.

O. virgata, Sil. System, pl. 20, fig. 15; Siluria, 2nd ed., pl. 5, fig. 9.

We have but one valve of this, and Sowerby only figured the same valve in the Silurian system. It agrees in shape pretty well with *O. plana*, or *O lata*, Pander, having the hinge line somewhat shorter than the width of the shell. But it is a larger form, and has numerous, (36 or more,) ribs, very regular and equal in size.

Locality.—CARADOC. Cwm-gwynen-uchaf, Montgomeryshire.

Var. *simplex*, M'Coy.

Pl. 22, fig. 4.

Orthis simplex, Sil. Syst. Ireland, pl. 3, fig. 18.

This, which is a convex shell, is wider than any of Pander's varieties, though most like his var. *rotundata*. It is a small shell too, and has about 32 (M'Coy says 24) equal ribs. But its wide form helps to conduct us to the following, which is a mere variety.

O. simplex has well defined longitudinal and cross striæ, rather thicker hinge teeth than usual, and the space for the muscular impressions in the ventral valve is narrower than that in the majority of varieties.

Locality.—CARADOC, of Waterford, common.

Var. *plicata*, Sowerby.

Pl. 22, fig. 5.

Siluria, 2nd ed., pl. 5, fig. 7; Sil. System, pl. 21, fig. 6.

The hinge line is very wide, both valves are convex, the hinge area large and high, and the ribs are numerous, and, though regular and rounded, are frequently interlined. They are at least twice as numerous as in any of the previously described varieties. They show the cross striæ and frequently a longitudinal stria in the hollow between two ribs. Interiorly the teeth of the dorsal valve diverge very regularly, and these and the long thin central tooth or cardinal process are of the same proportions as in the other varieties. In a good Bala specimen, flat case 8, No. 27 ($\frac{8}{27}$), since figured by Mr. Davidson in his Mono. Brit. Sil. Brach. Pal. Soc., 1866–71, p. 245, t. 35, f. 25–26, the hinge area is very broad, and the deltidial fissure very narrow. The cavity for the muscular impressions in the ventral valve is strongly ridged across the sides, and the vascular rays very strong quite up to the hinge plate, and also a good deal branched. The shell seems to have been rather thick.

Locality.—CARADOC. Bala.

Var. *Wallsalliensis ?* pl. 22, figs. 6, 7.

O. Wallsalliensis, Davidson, Bull. Soc. Geol. France, 2nd series, vol. v., p. 339, pl. 4, fig. 7; Lond. Geol. Journ., pl. 27.

This might be described as an extreme form of var. *plicata*, for its shape agrees well. But there are the following differences, which bring it nearer to the var. *Wallsalliensis* of the Upper Silurian (ours is a Lower Llandovery variety).

The dorsal valve is more convex than in *O. plicata*, and the ribs, instead of being numerous and slightly interlined, divide into bundles of twos and threes from very near their origin, and again sometimes branching at half way down form fascicles of four or five ribs. There is an approach in the very numerous ribs to the *O. rustica*, Sow., which is also a variety. That shell and *O. rigida* are however square and depressed, the latter furrowed down the middle. The shell here figured is in any case an extreme form, and yet the general aspect of the ribs, their rod-like form, cross striæ and regular intervals, above all the form and size of the interior teeth of the upper valve, decide me in referring all these varieties to one species.

Locality.—Lower Llandovery, Gas Works, Haverfordwest; CARADOC of Cefn Llwydlo, Brecknockshire.

It would be very difficult to say wherein any of Pander's varieties differ more than different individuals of ordinary species differ. And though there seems a wide interval between the type or the Llandeilo variety and the Llandovery and Wenlock forms, it is not difficult to show such a gradation from one to the other as would satisfy any impartial student.

For the present it may be convenient to retain the names—

O. calligramma.
O. rustica (including *rigida*).
O. plicata (including *virgata*).
O. Wallsalliensis.

They probably all came from one stock, and that may have been the small and simple-ribbed form that we find in the Lower Llandeilo beds, pl. 11 B., fig. 12. The range from Lower Llandeilo to Wenlock Limestone is a considerable one. The species may nevertheless in its more typical forms be considered characteristic, as the author of Siluria insists repeatedly, of Lower Silurian rocks.

Orthis calligramma, Dalm., junior.

Pl. 11 B, figs. 11, 12. Pl. 12, fig. 5.

These small specimens appear to be in nowise different, except in size, from the ordinary forms of this species.

Locality.—ARENIG. Under the traps of Manod Bach, Ffestiniog, at a place called Cae-glyd, a locality rich in fossils and well worthy of search. Also in the arenaceous mudstones of Lords Hill, and other places west of the Stiper Stones, Shropshire.

Orthis alata ? Sow.

Pl. 11 B, fig. 13.

Siluria, 2nd ed., Pl. 5, fig. 6.

Too wide for any varieties of *O. calligramma*, with which it occurs near Shelve. *O. alata*, Sow., has, however, besides the extremely wide form, so unusual for *Orthis*, a distinctly smaller set of ribs at the angles, which are not present in our specimen. It may be the young state of the species. The ribs are, with this exception, like those of *O. alata*, but they are also like the varieties of *O. calligramma*, to which species it cannot belong.

Locality.—ARENIG, Lords Hill, Shelve.

Orthis, sp.

Pl. 11 B, fig. 14.

A small species, with few dichotomous and interlined ribs, which cannot be referred to any varieties of *O. calligramma*.

Locality.—ARENIG, Mytton Dingle; and Cefn Gwynlle, west of the Stiper Stones.

Orthis flabellulum, Sow.

Pl. 21, figs. 9–16.

Siluria, 2nd ed., pl. 5, f. 12.

O. rotunda, transversa, cardine brevi. Valva dorsalis valde convexa, sinu nullo;—altera plana. Costæ simplices rotundatæ, per medium et ad marginem 2-vel 3-furcatæ, haud nisi striis concentricis lineatæ. Processus cardinalis ovatus.

The principal varieties of this fine shell are figured, which is not only a characteristic but a very common one in all the Caradoc deposits, and so far as we know never ranges beyond them into higher or lower beds or is known to occur outside the British area.

It is useless to go into a minute description of so well-known a shell; suffice it, that it differs at once from *O. calligramma* and all its varieties, by having the ventral or larger valve flat, and the dorsal convex without any median furrow. The interior characters are also widely different, the teeth thicker and larger at the end, the central or cardinal process broad, and shorter than the diverging teeth, much in the same way as they occur in *O. porcata*.

The muscular impressions (v. valve) are remarkably strong and square, very much after the pattern of those in *O. porcata*, which is an extremely close ally, though much more irregular in its striæ.

The ribs of *O. flabellulum* are simple and rounded, as broad as the intervening furrows; and like them destitute of longitudinal striæ, but marked by close transverse lines of growth.

A few strong fringe-like varices of growth occur near the margin, giving the old shell an antiquated aspect, and at about half way down the shell the ribs fork in most of the varieties, and in many specimens fork again; when this is the case the ribs become angular instead of rounded.

In the extreme variety (var. *multifida*) from Snowdon, fig. 17, the number of ribs is greatly increased, but we are already prepared for such variations by the parallel case of *O. calligramma*. It doubtless belongs to the present species; and nearly the same variety occurs at Llanfyllin, Montgomeryshire.

Fig. 15 shows the general section of the shell, contrasting strongly with that of *O. Actoniæ*, pl. 21.

Locality.—North Wales and Shropshire, everywhere in CARADOC rocks.

Orthis porcata, M'Coy, var. *retrorsa*, Salter.

Pl. 19, fig. 4.

O. porcata, M'Coy, Sil. Foss. Ireland, pl. 3, fig. 14, 1846; Billings, Canadian Reports, 1862, p. 135. *O. occidentalis, O. sinuata, O. subquadrata, O. subjugata*, Hall, Pal. N. York, vol. i., pl. 32 a, b, c, pp. 126, &c. *O. inflata*, Salter, Quart. Geol. Journ., vol. i.; Mem. Geol. Surv., vol. ii., pt. 1; var. *retrorsa*, pl. 19, fig. 14. *O. inflata*, var. *retrorsa*, Salter, Mem. Geol. Surv., vol. ii., pt. 1, pl. 27, fig. 3. *O. retrorsa*, Billings, Canad. Rep., 1862, p. 136, fig. 112, *O. Carleyi*, Hall, 13th Reports of the Reg. Univ., p. 120. *O. grandis*, Portlock.

One of the commonest of Lower Silurian forms, and as such it has been described in its numerous varieties under many different names. In the Western States of America it is even more frequent than with us, and found in a more perfect state than even in Britain.

M'Coy's imperfect specimen was doubtless the first described and figured, and his name must be preserved. But the species exists in such abundance in America, and varies so widely, as to have received a great many names, a few of which are given above. It is known in the Western States under the name *O. formosa*.

The species is more nearly allied to *O. flabellulum* than might at first be supposed, and like it has the dorsal valve highly convex, and the ventral valve flat or concave. Except in the irregular ribs, which are only to be found in some extreme varieties of *O. flabellulum*, there is but little difference between them. The specimens referred by Portlock to *Orthis grandis* are only fine varieties of this shell. *See* Mus. Pract. Geology.

Locality.—CARADOC rocks, all through Shropshire, S. Wales, and Ireland.

· *Orthis Actoniæ*, Sow.

Pl. 21, figs. 1–8.

Siluria, 2nd ed., pl. 5, f. 11.

O. semiovalis, cardine longo. Valva dorsalis concava, sinu nullo; altera valde convexa fere involuta. Costæ paucæ, valde angulatæ, profundæ, minoribus interlineatæ, et ad marginem sæpe confertæ. Processus cardinalis ovatus.

Of this we give complete figures, and point out the characters on which we may rely to separate it completely from *O. flabellulum*. There is no danger of confounding it with any other British species.

First, the relative convexity and concavity of the two valves is different in each. In *O. flabellulum* the receiving (ventral) valve is the flat or slightly concave one; in *O. Actoniæ* the reverse is the case. *O. flabellulum* has a hinge-line shorter than the whole width of the shell; in *O. Actoniæ* it is much wider, and produced into sharp ears. The former has rounded, the latter sharply angular ribs. And lastly, in *O. flabellulum* the ribs bifurcate; in *O. Actoniæ* they are simply interlined by other ribs (which towards the margin give rise to a cluster of small ribs).

There are no longitudinal and but few transverse striæ; sometimes these last are sharp and distinct. But a few distinct varices of growth are always present, and it is beyond the last of these that the sudden multiplication of the ribs takes place, which gives so curious an appearance to our fig. 3, and which has been well figured in Siluria.

Internally the dorsal valve (figs. 5, 6) shows thick slightly divergent teeth, and a narrow cardinal process (fig. 5), and the lamellæ which bound the muscles in the other valve are wide apart, much more so than is indicated in our fig. 3. The areæ are moderate and equal in either valve.

Localities.—Everywhere in Wales and South Ireland in CARADOC rocks. In LOWER LLANDOVERY in South Wales, *e.g.*, Haverfordwest; Mandinam, in Caermarthenshire; Mathyrafal, in Montgomeryshire, &c.

Orthis lenticularis, Dalm.

Pl. 4, figs. 8–10.

Atrypa, Dalman, Kongl. Veteusk. Acad. Hand., 1827 (1828), p. 48; *Spirifer*, Von Buch, Berl. Akad, 1834, t. 1, figs. 13, 14; Jahrbuch, 1834, p. 616.

A well marked and very pretty species, and the earliest known in British rocks. It is hardly ever more than one-third of an inch wide, and most specimens are not half that size. The length is less than the breadth in proportion as seven to nine. Our figures represent the shell as distorted in various positions, but the above is about the average measurement. Both valves are somewhat convex, but the dorsal valve has a broad central depression of a triangular shape, bounded by two rather prominent ribs out of the 10 or 12 strong ones which radiate from the beak, and the sinus is occupied by two subcentral and very distinct ones. The lateral ribs are strongly interlined by others half way up, the intervening ribs soon becoming as strong as the primary ones, and these again by shorter and smaller ones in the intervals. All are crossed by strong but interrupted and rather wavy ridges of growth, so as to decussate the surface in rather a remarkable way.

The other valve is like in sculpture, but has a rather prominent beak, fig. 10*a*.

The number of ribs varies greatly, but not in a way to make me believe we have more than one species. Sufficient differences are not seen in Scandinavian specimens* to warrant us in separating these, which occur in abundance in the alum slates in limestone layers.

The teeth diverge slightly in both valves; in the dorsal valve they are subparallel and short, or even curve a little inward, and are not thickened; while the cardinal process between them is a mere line or thin edge, which extends as far down as the length of the short lateral teeth, but is often very obscure, and sometimes seems to be altogether absent.

* From Kinnekulle, W. Gothland. In the choice cabinet of John E. Lee, Esq., of Torquay.

There is little doubt this is Dalman's species from Egeberg, though the specimens we have from thence have less prominent ribs, and a generally smoother appearance. There is no essential difference.

Locality.—Upper Lingula Flag, Penmorfa Church, Tremadoc; near Criccieth, at Ogof-ddu cliff.

Orthis alternata, Sow.

Pl. 19, figs. 11–13.

Siluria, 2nd ed., pl. 6, fig. 5. Sil. Syst., pl. 19, fig. 6. *O. retrorsistria*, M'Coy, Synops. Woodw. Mus., t. 1 H., figs. 12, 13.

The original figure by Sowerby in the Silurian System is from the typical variety so common in the "Jacobstones" of Shropshire. But the smaller and wider form figured here (from an unpublished plate in the possession of the Geol. Survey) is far more common in Wales, and we are able to show in it the large central tooth in the dorsal valve, which proves it, notwithstanding its resemblance to *Strophomena*, a true *Orthis*. The very large ventral muscles are peculiar and characteristic. There is altogether a curious imitative appearance about this shell. Fragments have been constantly mistaken for *Strophomena expansa* or *Leptæna sericea*. To both genera it has some relation.

Locality.—Caradoc slate rocks throughout Wales and Shropshire.

Orthis striatula, Conrad.

Pl. 13, figs. 10–14.

O. striatula, Conrad, sp. Emmons, Geol. Report, 1842, 394, illust. 105, fig. 3. *O. testudinaria*, Hall, Pal. N. York, vol. i., pl. 32, fig. 1. Salter, in Mem. Geol. Surv., vol. ii., pt. 1, pl. 27, figs. 6–8. *O. striatula*, id. in Siluria, 2nd ed., p. 544, foss. 10, fig. 16, 33 f. 3; Quart. Geol. Journ., vol. xv., pl. 13, figs. 14–16.

Our specimens from the Upper Llandeilo flags of Caermarthenshire are larger and finer than any figured in American works. The *O. striatula* is a very common shell in the Trenton limestone and associated strata of America, and Hall figures it of a medium size. But his description specially recognises the distinctive character, the fine, close, elevated, thread-like concentric lines, which cover the surface and crenulate the ribs.

It has a remarkably flat dorsal valve, rather a long hinge line for the group, and but slightly diverging cardinal teeth, between which the narrow cardinal process is most prominent near the hinge margin; the ridge dividing the muscular impressions is very broad and low. A few antiquated lines of growth vary the surface in some larger specimens.

Locality.—Arenig: [Lords Hill, Shelve?], Sutherlandshire, as above, Quart. Geol. Journ. Llandeilo: S. Wales. Caradoc? Lower Llandovery: north of Llandovery.

Rhynchonella ——, sp.

We need only mention here that a species, if not more than one, of this genus is rather abundant in some parts of the Caradoc rocks of North Wales.

The *Rhynchonellæ* in the Caradoc have been variously and erroneously referred to several Upper Silurian forms. Portlock has no less than three Upper Silurian names (*T. crispata, T. plicatella, T. pulchra*) for differently compressed varieties of a common Tyrone species, which however is not perfect enough to name. It is distinct from the Upper Silurian species quoted, and appears to be identical with the one common along the rocky banks of Llyn Ogwen, in all the lower fossil bands near the foot of the lake.

The species is not unlike the Llandovery species, *R. serrata*, described from Galway by Professor M'Coy (Sil. Foss. Ireland, t. 3). The ribs are about as numerous as in the Irish species, in some specimens at least, but in none are there more than five ribs elevated; they stand up higher than in *R. serrata*, and the hinge plates within are thicker.

Lamellibranchiata.

Cyrtodonta, Billings, 1858; *Palæarca*, Hall, 1859.

[Family *Arcadæ*. Very inæquilateral, rhomboid ovate, ventricose, posterior ridge expanded. Umbones anterior. Anterior muscular impression deeply sunk, the posterior obscure. Hinge area undefined, hinge plate thick, arched, with a few (three) anterior cardinal teeth, placed beneath or in front of the umbo; and two or three remote oblique posterior teeth parallel to the hinge margin. Surface generally smooth, the siphonal ridge and posterior area only obscurely marked out. Pallial line simple. Ligament?]

Though inclined, as all naturalists must be, to admit the claims of priority wherever it is possible, it is not desirable at all to restore old and unmeaning names in preference to the one imposed by the first real describer. To insist on this would be to revive the old useless catalogues by collectors and dealers in place of a scientific nomenclature. This practice was justly condemned by the late Dr. Woodward in his excellent work on the Mollusca, and in England the opinion which Forbes so strongly advocated is becoming general, that the rule of priority should be strictly observed only in regard to species.

The name of the present genus, one very common in the old rocks, is a case in point. It has simultaneously received two scientific appellations, each accompanied by a clear and sufficient description, when it was discovered by Professor Hall that his carefully described genus had been previously included, as to one of its typical forms, in the heterogenous group *Cypricardites*, proposed however by a real naturalist, Conrad. That genus is not only insufficiently described by Conrad (who included in it some forms of *Grammysia*), but the name is a misnomer, lending belief to the old idea that *Cypricardia* had numerous allies in the Palæozoic rocks. Its affinities are wrongly stated, and it is compared with *Pterinea* instead of *Arca* and *Nucula*. A species necessarily represents but a single form, and a host of difficult synonyms are avoided by the adoption of the first post-Linnean name. But genera are more or less abstractions, and always require great judgment in forming them. The general adoption of the first well-considered name, if accompanied by an intelligible description, is indeed most desirable, while the law of priority enforced without this safeguard would barbarise our nomenclature by depriving the names of our groups of all scientific meaning. Conrad's plate in 1841 was to supplement his descriptions during four years in the annual reports (*see* Reports Reg., No. 15, 1862). The imperfect description then had the advantage of a figure, and, had this figure been intelligible, Professor Hall, would only have been too glad to have availed himself of the name, as he has done in other cases. But the group included various forms, and Professor Hall, who separated *Modiolopsis* from it, does not appear to have recognised the typical form of *Cypricardites* till afterwards, when he had obtained good specimens of *Palæarca*. *Palæarca* appears to have been in print 1847, but unfortunately it escaped the notice of Mr. Billings, as it seems to have done that of all others. *Cyrtodonta* appeared in 1848 beautifully illustrated, while Hall's figures were probably already engraved for his third volume. [*See* Reports of the Regents of the Univ. New York, 12th, 13th, and 15th, 1859, 1860, 1862; Billings, in Reports Geol. Survey, Canada, for 1857, published in 1858; New species (*Vanuxemia*), 1857, id.; New Species, &c., June 1862; and Canadian Journal for 1861, p. 354.]

Palæarca Billingsiana, n. sp.

Woodcut 12, f. 4.

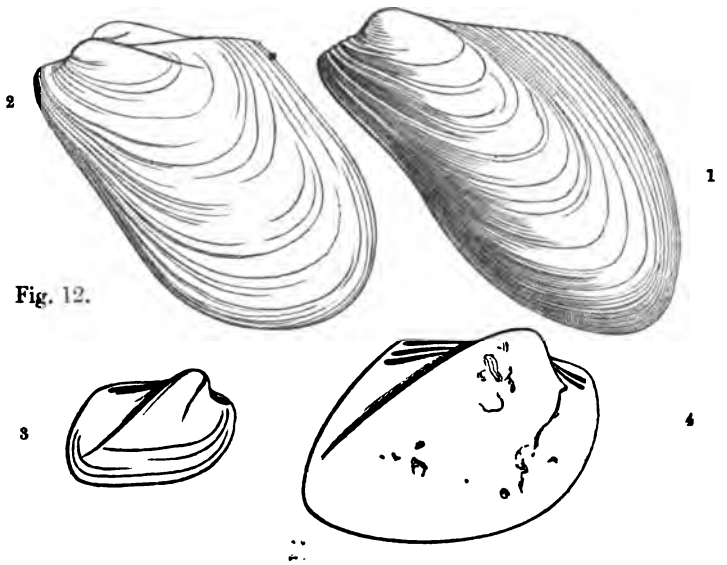


Fig. 12.

1. *Modiolopsis pyrus*, Salter.
2. *Palæarca modiolaris*, Salter.
3. *Palæarca quadrata*, n. s.
4. *P. Billingsiana*, n. s.

Shell obliquely rhomboid, ovate and rather compressed, 1½ inches long, and 1 inch high, depth of valves united 7-10ths of an inch. The beak is anterior, beyond the anterior fourth, the posterior side bluntly angulated, and much broader than the somewhat pointed anterior; the beak small, and pointed, the siphonal ridge strongly marked from it to the posterior angle; making the cardinal slope steep and almost vertical behind the umbo. The hinge plate narrow, with three radiating posterior teeth (in the left valve) and two anterior (cardinal) which lie parallel to the hinge margin, not across it. Anterior muscle not very deep. The lines of growth in this rather thick shell are not distinct, but we have only the inner cast. It is a compressed shell, otherwise it is much like in general character *P.* (*Cyrtodonta*) *Headi*, lately published by Billings from the Hudson river group (or Caradoc), of Toronto Canadian Reports, June 1862, p. 151). That more gibbous species is also more oblique than ours, and assumes just such a shape as ours would, if pressed obliquely from the hinge. But the American species are in better preservation than our own, and we must keep the forms distinct.

Locality.—Caradoc Slates, Nant Jorwerth, S. of Llangollen.

Since Mr. Salter wrote the foregoing notice, two species of the genus have been found by Dr. Hicks in the Tremadoc beds of St. David's and Ramsey Island, but none are known in the Upper Silurian.

Palæarca, Hall, 1859.

Palæarca Hopkinsoni, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 48.

This species and *P. obloidea* are the two oldest known forms of the genus. Two other species occur in the Arenig beds and five in the Caradoc, but none occur in the Upper Silurian rocks of any area in Britain. *Palæarca* is widely distributed through the American Silurians.

Formation and Locality.—Tremadoc. Ramsey Island and St. David's.

Palæarca oboloidea, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 48.

Formation and Locality.—TREMADOC. Ramsey Island and St. David's.

Palæarca obscura, Salter.

Woodcut 13, f. 2.

Shell obliquely convex, and with the posterior side greatly enlarged, the beak almost lateral. The whole shell ventricose, thick near the hinge, the area of which is almost at right angles to the general direction of the shell. The beak placed somewhat nearer the anterior end of the short hinge plate, on which no posterior teeth are visible: the anterior are short and thick, three strong ones, separated by deep broad pits, in the left valve, overhanging a very deep round muscular scar supported on the usual subcardinal ridge, in this case thick but not sharply defined.

Our figure represents the internal cast, and a view of the hinge plate. In the rounded form and very inæquilateral proportion, this shell most resembles *P.* (*Ambonychia*) *obtusa*, Hall, or the *P.* (*Vanuxemia*) *inconstans*, Billings, Canadian Reports, 1857, figs. 13, 15.

Locality.—CARADOC, Bala.

Palæarca? modiolaris, Salter.

Woodcut 12, f. 2.

Oblique, posterior side much expanded, rounded and compressed; anterior small, rounded, somewhat divided from the body of the shell by a slight sinus; beak almost lateral, convex, scarcely tumid, and the siphonal ridge very slightly marked; hinge area very narrow, teeth—?; surface smooth, except occasional rugosities, the anterior side strongly striate. Length 2 inches, breadth across the posterior side 1¼ inch. Depth of valves united 1 inch.

The shell has much the aspect of a *Modiola* or *Modiolopsis*, but though no hinge teeth can be seen, we are safe in referring this straight-hinged shell to such oblique-ovate species of the genus as *P.* (*Cyrtodonta*) *canadensis*, Billings, and *C. Harrietta*, id. (Reports, 1862). Billings' genus *Matheria* must be included in *Palæarca*.

Locality.—CARADOC, Bala.

P. (*Matheria?*) *quadrata.*

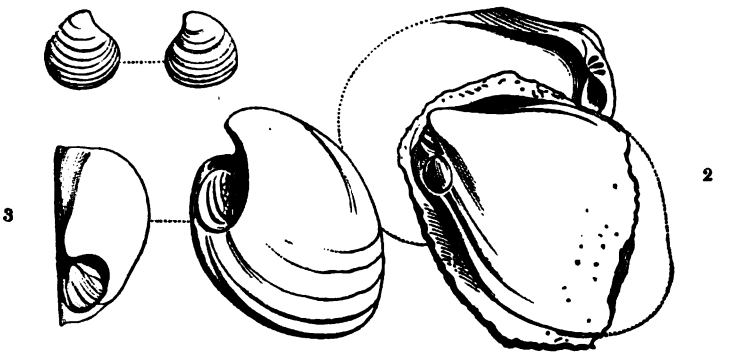
Woodcut 12, f. 3.

Shell oblong transverse, the posterior side not at all broader than the anterior, both ends somewhat truncate, beak prominent anterior, overhanging a distinct supine lunette; a strong siphonal ridge from the beak to the posterior angle, and another ridge marking off the anterior slope. These ridges are strong near the beak, but the anterior one becomes faint as it proceeds downwards. Shell thin, posterior teeth 2 in right valve. Anterior (two?) strong. Only one of the anterior teeth can be distinctly seen, it is parallel to the hinge margin. The shape of the shell is unusual for the genus, more like an *Edmondia* or *Orthonota*. It is, however, very like *Matheria tener*, of Billings, and also a thin shell. If *Matheria* is only a section of *Palæarca*, the occurrence of two posterior teeth in the present species would help to connect the type species (*M. tener*), which has none. *Cyrtodonta subcarinata*, Billings, resembles it, but is too narrow a form, with the usual hinge of *Palæarca*, which has several teeth.

Locality.—CARADOC of Bettws-y-coed, N. Wales.

It is very probable that several of the so-called *Dolabra* (M'Coy) may belong to this genus.

Fig. 13.



1. *Ctenodonta varicosa.* 2. *Palæarca obscura.* 3. *P. bulla.*

Palæarca? bulla, Salter.

Woodcut 13, f. 3.

P. ? rotunda, inflata, tenuis, rugis concentricis nonnullis antiquata. Umbones curvi, lunulam anticam profundam impendentes. Cardo dentibus tribus minutis anticis, postico unico. Musculi antici profundi.

Mr. Salter believed this might form the type of a new genus, but refrained from adding to the already overburdened nomenclature until more specimens of the species had been collected; he referred it to *Palæarca* because that genus stands sufficiently near to indicate its relationship to the *Arcadæ*, and is a type containing several subgenera; and not to *Megalomus* which it resembles externally, seeing that is a massive shell and ours is a thin inflated one. *Megalomus* too has a sub-umbonal ridge remote from the muscle, no posterior tooth, and a thick laminated shell. It is probably, notwithstanding its pedal scars, one of its allies, and one of the *Arcadæ*.

The species has the deep anterior muscle, and the anterior teeth of *Palæarca*, and the subcardinal ridge bounding the muscular scar is strong, as in many of the Silurian *Arcadæ*. The posterior muscle is large and triangular, but ill-defined.

The anterior (cardinal) teeth 3 in the left valve, unequal in size, set on a rather thick hinge plate; a single strong remote tooth on the posterior side. All this bears on the generic character and its relation to *Arca* and *Nucula*. But the general form, inflated, round, with curved approximate beaks, reminds one of *Isocardia*, or at all events of *Cypricardia*, to which it has no manner of affinity.

Localities.—Caradoc, Llanfyllin, N. Wales; S. of Llangollen, N. Wales; Horderley, Shropshire, abundant. (Mus. Pract. Geol.)

Palæarca socialis, Salter.

Pl. 11 A., fig. 13.

P. (? dubia), haud longitudinem unciæ attingens, transversè ovata, lævis, nisi, lineis incrementi distinctis notata; latere antico brevi rotundato, postico producto nec angulato. Umbones elevatiores.

Shell three-quarters of an inch wide, and nearly 5 lines high, moderately convex, smooth, or with lines of growth only. The beak is near the rounded anterior end, but not very prominent; the posterior side produced but not angulated. The back straight, the ventral edge a little sinuated beneath the beak.

The whole form, in its uncompressed and undistorted form, is that of an *Arca;* but the extraordinary shapes it can take in the rock may be seen by the figures 13 *a. b.* They might easily be mistaken for as many species.

It is to be observed carefully that the earliest *Lamellibranchiata* known are everywhere referable to the *Modiola* or *Arca* groups, chiefly the latter. For this suggestive generalisation we have been long indebted to Professor Phillips (Mem. Geol. Surv., vol. ii. pt. 1., pp. 263–275). (Lamellibranchiata lists, &c.)

Locality.—ARENIG BEDS.—Ty-obry, Penrhyn, opposite Tremadoc (abundant).

Palæarca amygdalus, Salter.

Pl. 11 *b.*, fig. 17.

P. transversa, obliqua, mytiliformis, (curva ?) convexa fere gibba; latere postico elongato, antico nullo ferè. Umbo convexiusculus omnino terminalis, tumidus. Lunula minuta. Lineæ incrementi creberrimæ, validæ, majoribus squamatis remotis mixtæ.

A pretty species. For want of the interior the genus is uncertain, but it is like the figures given by Billings of the genus *Cyrtodonta*, which genus, as before said, appears to have been previously described by Hall as *Palæarca*. The obsolete anterior side is characteristic.

The shell is mussel-shaped, but for the rounded anterior end, and the curved general shape. It is obliquely gibbous, the diagonal convexity as well as the shell being bent rather than curved upwards. The dorsal edge is concave, the ventral highly convex, and the valves meet at a very obtuse angle—almost vertical in front, less so on the somewhat broader and posterior side.

The umbo is convex, but not much prominent, and is quite terminal, overhanging a small deep lunette on the very short obtuse anterior side.

The surface is marked by close sub-equal concentric lines, among which stronger ones here and there indicate the varices of growth. These become more numerous near the very obtuse front margin, where the valves meet one another all but vertically. The length of the valves is nearly 10 lines, the height 6 lines, the depth of the united valves 5 lines.

Locality.—ARENIG. Cefn Gwynlle Mine Works, N. of Linley Hall, Norbury.

Glyptarca, Hicks, 1873.

Glyptarca, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 48. 1873.

This genus was established by Dr. Hicks in 1873 to receive *Arca* like species occurring in the Tremadoc rocks of St. David's. They are, so far as we know, essentially Tremadoc, and confined to the South Wales area. Both species seem abundant at Ramsey Island and Tremaenhir, St. David's.

Glyptarca primæva, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 48.

Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

Glyptarca Lobleyi.

Quart. Journ. Geol. Soc., vol. xxix., p. 48.

Locality and Formation.—TREMADOC. Ramsey Island, near St. David's.

Tellinomya, Hall, 1847. *Ctenodonta*, Salter, 1852.
(*see* Siluria, 2nd edit., p. 213.)

The shells to which this name is applicable have been long known as species of *Nucula, Leda, Arca*, &c. in the old rocks. The discovery of very perfect specimens by Sir W. Logan in Canada first showed the true characters of the group; the external ligament being a striking distinction between it and ordinary *Nucula*. In other respects the palæozoic (probably excepting many of the carboniferous) species are like the deep-water genera above quoted, some having a short posterior side like *Nucula*, others a long one as *Leda*. Usually the form is transverse, but in a few the shape is very short and trigonal, and the following species is remarkably so. We have distinguished the genus from the *Isoarca* of Munster in the Canadian Decades, No. 1. S. Woodward included it with that genus.*

* Manual of Mollusca, p. 427. Ed. 1868.

Ctenodonta varicosa, Salter.

Woodcut 13, f. 1.

Nucula varicosa, Salter, Quart. Geol. Journ., vol. x., p. 75; *Ctenodonta*, Siluria, 2nd edit., p. 213; *Nucula levata*, M'Coy, Synopsis Woodw. Museum (not of Hall).

This species is very common in the Caradoc rocks (of North Wales particularly). It has been fully described by Mr. Salter in the Geol. Journ. above referred to. Its triangular shape, and extremely high and curved umbo, would almost distinguish it from any species except the *C. astartæformis* of Canada (Canad., Dec. 1, Pl. 8, f. 7). Sharp, concentric, step-like lines of growth occur at pretty regular intervals over the surface, and give it a peculiar aspect. The *N. levata* of Hall has simple concentric striæ only.

Locality.—CARADOC sandstone and slate, everywhere; Bala; Conway falls; Montgomeryshire, &c.; Horderley.

Ctenodonta Menapiensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 47. 1873.

Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

Ctenodonta Cambrensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 47.

C. elongata, Hicks. Camb. Cat., p. 24, *? C. rotunda.*

Locality.—TREMADOC. Ramsey Island and Tremaenhir, St. David's.

Redonia, Roualt, 1851.

Redonia anglica, Salter.

Pl. 11 B., fig. 15.

(*Cucullella ?* Siluria, 2nd edit., p. 50, Foss. 8, fig. 2.)

Transverse ovate, half an inch wide, one-third of an inch long, very convex and regularly so, with the beak overhanging the broadest part of the shell at the anterior fourth. The beak is curved and sharp, and much overhangs the lunette. In front of it a strong, thick, rather curved plate reaches obliquely more than half way down the front side; the muscular impression being deeply imbedded in advance of it, short-triangular, and strongly circumscribed. The casts vary a little in shape, some being more convex. But the shape is always transverse, not rounded; and ovate, not triangular. (By some error, hinge teeth are inserted in the figure above quoted. There are no posterior teeth.) It is not unlike *Redonia Deshayesiana*, Rouault, as figured by Sharpe in the 9th vol. of the Quart. Geol. Journ., but is too regularly oval. It is still more like the *Nucula Beirensis* of the same communication, yet it is a shorter, less rounded species, and even more convex.

Locality.—ARENIG. Lord's Hill, Shelve.

Ribieria, Sharpe, 1853.

Ribieria complanata*, Salter.

Plate 11 B., fig. 16.

(*Redonia*, Siluria, l. c., fig. 3; *Ribieria*, in pp. 20 ? 549.)

R. minor, valde compressa, subquadrata, margine dorsali et ventrali parallelis lentè curvis. Impressio muscularis posticus obscurus. Lamina antica brevis, recta, ad basin crassiuscula.

Although there is some uncertainty as to the group to which this curious fossil belongs, it is clearly distinct as a species from one described by Sharpe. Its dorsal edge is nearly straight, the posterior side as wide (even in the cast) as the anterior, and the whole shell is very much thinner than the Spanish fossil. The oblique anterior plate (a deep notch in the cast) is straight, sharp-edged, and extends across rather more than one-third the breadth of the shell

* A genus proposed by D. Sharpe, Esq., for a single species from the Lower Silurian rock: Busaco, Spain. The genus has since been found in Bohemia, France, and Devonshire.

anteriorly. It is sharp-edged, except at the base, where a small abrupt thickening takes place (while in the Spanish species the plate is broad and thick). The posterior muscular impression is scarcely visible.

Locality.—ARENIG. Lord's Hill, Shelve.

Davidia, Hicks, 1873.

Quart. Journ. Geol. Soc., vol. xxix., p. 49.

The two species placed by Mr. Hicks under this generic name are so *Tancrediform* and *Donaciform* in shape that in more modern rocks they would probably be classed as one of those genera. These, with the species *Palæarca* and *Glyptarca*, are the oldest bivalves known, none being present in the Menevian or Lingula flags in any area.

Davidia ornata, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 49. 1873.

Formation.—TREMADOC. Ramsey Island, near St. David's.

Davidia plana, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 49.

Formation.—TREMADOC. Ramsey Island, near St. David's.

Modiolopsis, Hall, 1847.

Modiolopsis pyrus, Salter.

Woodcut 12, f. 1.

M. magna, 2½ uncias longa, 1¼ lata, inflata; latere antico acuto distincto minuto striato, postico elongato rotundo. Umbones obtusi, haud eminentes: margo cardinalis abbreviatus.

A peculiar aspect is given to this fine species by the regular convexity or rather inflation of the whole shell from the small beak outwards, the convexity not forming a siphonal ridge, but including the whole of the large posterior side, and only faintly distinguished by a slight sinus in the margin from the short acute and strongly striate anterior lobe.

The *M. modiolaris* of M'Coy (Pal. Foss. 1. I., fig. 17) is not an uncommon fossil in the Bala beds. But a comparison with Canadian specimens of the true *M. modiolaris*, Conrad, shows that the latter (though very like our British shell when Hall's good figures are compared) differs materially from the English species in being much flatter, having the anterior lobe both larger and less distinct from the body of the shell; the posterior side is also considerably less expanded than in the Welsh fossil, which should be called *Mod. M'Coyii*. We may take occasion to note how very few of the Silurian *Lamellibranchiata* are identical on the two sides of the Atlantic. The *Brachiopods* are much more like and allied.

Locality.—CARADOC. Bala, North Wales, not unfrequent.

Modiolopsis solvensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 50, t. 5, f. 18, 19.

Formation and Locality.—TREMADOC. Ramsey Island, Tremanhire, near Solva and St. David's.

Modiolopsis Cambrensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 50, t. 5, f. 20.

Formation and Locality.—TREMADOC. Ramsey Island.

Modiolopsis Homfrayi, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 49, t. 5, f. 16, 17.

Formation and Locality.—TREMADOC. Ramsey Island and Tremanhire.

Modiolopsis Ramseyensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 49.

Formation.—TREMADOC. Ramsey Island.

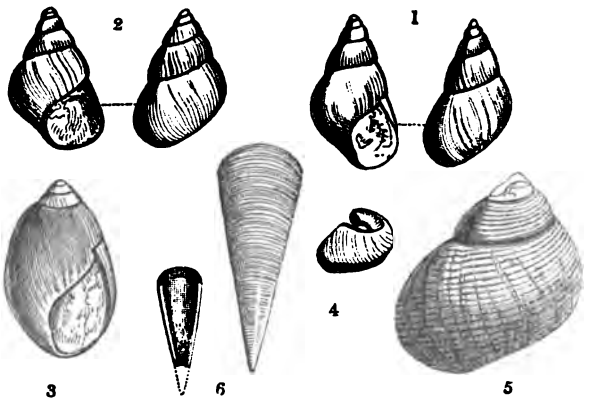
Gasteropoda.

Holopea, Hall. Palæontology of New York, vol. i., p. 169. 1842.

A genus instituted to include those smooth species of so-called *Turbo*, which are common in Silurian rocks, but which clearly do not belong to the operculated genus to which they are referred. The forms are very like *Turbo* in shape, but have no umbilicus; the pillar lip is closely reflected, and generally somewhat excavated. The typical forms are American. No very broad line can be drawn between this and the next described genus, *Cyclonema*, which, however, consists of more ornamented forms with concentric ribs or striæ. The whole group, *Holopea*, *Cyclonema*, *Trochonema*, &c., as described in Decade 1 of the Canadian Survey, belong rather to the *Litorinidæ* than the *Turbinidæ* (*see* Woodward's Manual).

The names of the following species were left in MSS. by the late Professor Edw. Forbes, who regarded them as allied to the floating genus *Litiopa*, and proposed to name them *Litiopsis*. Hall's genus, however, has the precedence.

Fig. 14.



1. *Holopea exserta*, Forbes.
2. *Holopea conica*, id.
3. *Holopea lymnæoides*, id.
4. *Holopea carinata*, Forbes.
5. *Cyclonema crebristria*, M'Coy.
6. *Theca reversa*, Salter.

Holopea exserta, Forbes, MSS.

Woodcut 14, fig. 1.

H. uncialis, sublævis, spirâ acutâ producta ∟ 30°; anfractubus 5, lente convexis, rotundis, haud angulatis, ultimo spirâ paullo longiore, suturâ simplici nec appressâ.

This species is the most common in the Rhiwlas limestone. It has rounded whorls, not very convex, and the basal one is moderately and regularly ventricose, without any contraction at the suture. It is rather longer (but not much so) than the whole spire taken together. The shell has the look of a *Bithynia*, or a short *Bulimus*.

Locality.—Caradoc or Bala limestone, Rhiwlas, near Bala, Merionethshire.

Holopea conica, Forbes, MSS.

Woodcut 14, f. 2.

H. uncialis, anfractubus 5, convexis, subangulatis striatis; spirâ abbreviatâ, quam anfractu basali multo breviore. Basis convexa, a latere subconvexo angulo

obtuso (in spirâ conspicuo) sejuncta. Striæ obliquæ, confertæ, vix regulares, nonnullis varicosis mixtæ.

Differs from the preceding by the less produced and rather blunt spire, formed of four gently convex whorls subangular below, the sutures strongly indented. The striæ of growth are oblique, sharp, tolerably close, but not regular; and are interrupted by rude ridges of growth near the mouth. The base is convex. There is no trace of an umbilicus. The shell has a general resemblance to the freshwater *Paludinæ*.

Locality.—Same as last, and a more abundant species.

Holopea lymnæoides, Forbes, MSS.

Woodcut 14, f. 3.

H. magna biuncialis, anfractu ultimo maximo elongato, ad basin effuso. Spira brevis. Sutura distincta nec appressa. Columella curva. Striæ rudes, obliquæ, prope orem ellipticum ut rugosæ.

A large species, putting one much in mind of the great *Lymneæ* or *Physæ* of the tertiary beds. Altogether these Bala univalves are very peculiar in character, and have little resemblance to Silurian shells.

Locality.—Same as last, rare.

Holopea? carinata, Forbes, MSS.

Woodcut 14, f. 4.

H. semiuncialis, valde depressa, anfractubus 3–4, subangulatis; ore subrotundo. Sutura distincta. Umbilicus apertus?

Shell very nearly resembling, externally, the three last described species; but having a much shorter spire, and more depressed form. It has a thin shell, an oblique mouth aperture, and subangular whorls. But no portion shows the striæ of the surface, nor is the spire sufficiently complete to judge if it might be associated safely with the genus in which it is temporarily placed.

From many circumstances,—the finely levigated nature of the deposit, its great purity, and the quantity of *Encrinal* and *Cystidean* remains in the Bala limestone near Rhiwlas,—it is probable the bed was deposited in deep water. *Cephalopods* are common in it. And these thin univalves, which we have placed as members of the *Litorinidæ*, were, with much probability, considered by Forbes as floating shells. *Litiopa* belongs to the *Litorinidæ*, according to Dr. S. Woodward. (*See* Manual.)

Locality.—Same as last.

Cyclonema, Hall, 1852.

Palæontology New York, vol. i.

This genus, proposed by Professor Hall, has been more fully described and its distinctive characters pointed out by Mr. Salter in the work above referred to (Decades Canadian Survey, No. 1). It has much the aspect of *Litorina*, but was certainly a thinner shell than our modern species. Hall perceived the natural group formed by these ribbed and striated shells around *C. bilix* as a typical species, though no one has yet been able to give sufficient characters to distinguish it. Salter separated the species with an open umbilicus (*Trochonema*) from those with a closely reflected and somewhat excavated lip.

Cyclonema crebristria, M'Coy.

Woodcut 14, f. 5.

Turbo crebristria, M'Coy, Synopsis Woodw. Mus., t. 1 K., fig. 36, 1 L., fig. 22. *Cyclonema crebristria*, Salter, in Appendix to Siluria, 2nd edit., p. 548.

Professor M'Coy has so well and thoroughly described this, under the ordinary name *Turbo*, that it is needless to repeat the description, and has compared its close striation and general appearance to that of *C.* (*Pleurotomaria*) *bilix*, Conrad and Hall. His figures, too, are both of them characteristic.

The shell was only moderately thick, the lines of growth very oblique, and rugose on the left whorl. The striæ, which are alternately larger and smaller

on the upper part of the whorl, are of equal size and rather close together on the lower half; but the transition is a gradual one.

In the casts, which are the most usual state, the suture is deep and strong. The base of the shell is convex, a little angular below.

One of the most common of all Caradoc univalves in Wales. Both Mr. Salter and also Professor Sedgwick found it in severel localities in the May Hill sandstone or Upper Llandovery rocks. The *C.* (*Euomphalus*) *granulatus* of Portlock is closely allied, but cannot be identified with ours.

Localities.—Caradoc or Bala. Everywhere in North Wales, Bala, Meifod, &c.; also Upper Llandovery rocks, Presteign, Radnorshire.

Ophileta or *Raphistoma*, sp.

Pl. 11 B, fig. 21.

A small species, not worth naming, but interesting as showing how nearly the fossils of the Calciferous sand-rock, and beds immediately overlying it, are represented in Britain by our Lower Llandeilo types. The specimen was presented by the late Mr. Lightbody to our cabinet.

To that gentleman, although his name is not often to be found in this memoir, geological science in England owes a real and lasting debt. Living at Ludlow, on the edge of the typical Silurian region, he made himself thoroughly acquainted with the geology of Shropshire, especially down to the horizon of the Caradoc strata. His name has now long been widely known, and his credit as an accurate and critical observer fully established. To his kindness and ready help the Geological Survey is largely indebted. We take this opportunity of publicly acknowledging it.

Locality.—Arenig. White Grit Mine, Shelve.

Ophileta, sp., Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 188, t. 11, f. 3.

Formation and Locality.—Upper Arenig. Llanvirn quarry, St. David's.

Haliotidæ.

Pleurotomaria Llanvirnensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 188, t. 11, f. 4.

This is the only representative of the *Pleurotomariæ* in the Arenig rocks, indeed, the earliest or first known in the Sil. group of Britain. The Llandeilo group possessing two species, *P. latifasciata*, M'Coy, and *P. thule*, Salt., the former an Irish species, the latter from the Durness limestones of the N. of Scotland.

Formation and Locality.—Upper Arenig. Llanvirn, St. David's.

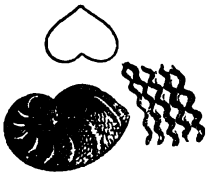
Heteropoda.

Bellerophon, Montfort, 1808.

Bellerophon nodosus, Salt.

Woodcut 15.

Fig. 15.



Lines of growth magnified.

Salter, Quart. Geol. Journ., vol. x., p. 73. *B. ornatus*, M'Coy, Syn. Woodw. Foss., p. 310.

Spire exposed, of about three rapidly increasing whorls, which are half as thick again as broad, and of a subrhombic section; the umbilical faces

rounded, and much shorter than the other flattened ones. Sides marked by thick raised ridges, which are not so broad as the intervening hollows; they are curved backwards towards the flattened dorsal keel, and nearly meet it, and extend over the rounded edge of the steep umbilicus. The lines of growth are beautifully regular, and they take a decided curve backwards along with the ridges. They are closely crenulate over the sides and back, and on the umbilical face reticulate with each other. Their reticulated appearance arises from the close approximation of the raised crenulate edges, which thus decussate each other, and become in some parts connected into a network. See magnified figure. The ridges or plaits vary in their distance from each other, but are very prominent.

This is the species described by Professor M'Coy, and we should have thought with him that it was *Cyrtolites ornatus* of Conrad, but that in Hall's figure and specimens we have from New York the lines of growth are direct across. In that species, too, the umbilicus has a sharper edge, and the plaits do not go beyond it. In ours it is obtuse, and they frequently run over it. Our shell is sometimes as large as the American species, and may possibly be identical, but there are the differences above stated.

Locality.—CARADOC SANDSTONE. Teirw River, south of Llangollen (Professor Sedgwick); Llwyn-yr-hwch, Beddgelert; near Llanfyllin; Hope Bowdler, Shropshire.

Bellerophon arfonensis, Salt.

Pl. 10, figs. 6-8.

B. latè involutus, uncialis et ultra, costato-striatus, striis remotis, arcuatis, asperis, etiam in sinu angusto vix marginato conspicuis; anfractu ultimo maximè dilatato, ore paullulum expanso (marginato?) Carina nulla.

An inch and a quarter in diameter, inflated; broad involute, the outer whorl greatly expanded, and deeply notched on the back. The lines of growth obscure, but accompanied by regular, sharp ridges at equal distances (in a specimen three-quarters of an inch diameter there are four in the space of a line). They show also on the notch or band, which is thus marked by prominent and rather remote arches throughout its whole length. Umbilicus open? Band not at all prominent, nor is there any depression of the whorl along it on either side. It is crossed by the arched striæ.

Fig. 6 may possibly belong to another species, as the lines, or rather ribs of growth, are scarcely visible, except on the younger portion. The lines or ridges of growth are parallel to the margin of the mouth, and are sharp and almost crested. In fig. 8 they are one-tenth of an inch apart, and yet this is a young specimen. Fig. 6 shows the mouth with the umbilical edge slightly recurved, but of course the shape is materially altered by pressure.

Locality.—UPPER TREMADOC. Garth, Penrhyn; also Tu-hwnt-yr-bwlch, Portmadoc. Several specimens have been found by Messrs. Ash and Homfray.

Bellerophon Ramseyensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 50 t., 3, f. 30–32.

Formation.—TREMADOC. Ramsey Island and St. David's.

Bellerophon multistriatus, Salter.

Pl. 10, figs. 9, 10.

Broadly involute, whorls rapidly increasing, umbilicate, with close arched striæ of growth (most conspicuous away from the umbilical edge), much curved, equidistant, and with numerous plaits or folds crossing them, which do not seem to indent the outer margin of the growth ridges, but only the spaces between, giving a fimbriated appearance.

It is easily enough distinguished from its companion species, *B. arfonensis*, figs. 7, 8, by the close and fimbriated ridges of growth. And it characterises rather an older set of beds, being chiefly found at the point of junction between the *Upper* and *Lower Tremadoc*.

Locality.—UPPER TREMADOC. North face of Moel-y-gest, Portmadoc, Garth, &c. Also at Llanerch, in the passage beds to LOWER TREMADOC. Cabinets of Messrs. Ash and Homfray, also of Dr. Ogle.

Bellerophon solvensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 50, t. 3, f. 33.

Formation.—TREMADOC. Tremaenhir, near Solva, and St. David's.

Bellerophon, hippopus, Salter.

Pl. 11 B, fig. 2.

B. latissimus, uncialis, striatus, vix costatus, anfractu ultimo maximè dilatato, striis inæqualibus conspicuis. Carina lata prominens. Apertura paullulum contracta. Umbilicus profundus.

Broad-involute, the outer whorl very wide, and rather depressed on the back with something of a furrow on each side of the broad band, which is rather prominent and well defined in all ages. Striæ arched backward, every third or fourth one stronger than the rest, but not producing prominent ridges as in *B. arfonensis*: nor do they form conspicuous ridges on the band as in that species. Umbilicus open, broad, deep.

Differs from *B. arfonensis* by the prominent band, less regular arched striæ, and unexpanded mouth, as well as by the extremely wide shape; the transverse being apparently much greater than the longitudinal diameter.

Locality.—ARENIG. Ritton Castle, west of the Stiper Stones.

Bellerophon Llanvirnensis, Hicks.

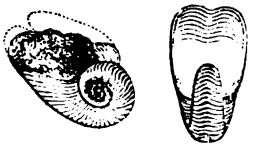
Quart. Journ. Geol. Soc., vol. xxxi., p. 188, t. 11, f. 1, 2.

Formation and Locality.—UPPER ARENIG. Llanvirn quarry.

Bellerophon perturbatus, Sow.

Euomphalus, Silurian System, Pl. 22, fig. 15. *Euomph. furcatus*, M'Coy, Sil. foss., Ireland, p. 13. *Bellerophon perturbatus*, Siluria, 2nd ed., p. 218, foss. 39, fig. 6.

Fig. 16.



Restored from good specimens. Upper Llandeilo, S. Wales.

We give a far better figure, from complete specimens, than was given by Sowerby in the Sil. Syst.

It has long been known that it was a *Bellerophon*, of the group *Euphemus*, M'Coy, and that *Euomphalus furcatus* of that last-named author was a synonym. It is not so generally known that it is one of the very best and most characteristic species for the *Llandeilo flags*, being common in British localities, in N. and S. Wales, and very rarely met with (in Ireland only) in rocks supposed to be of Caradoc age.

Locality.—LLANDEILO: Bath house, Bangor. Abundant in Llandeilo rocks in N. and S. Wales; and in CARADOC? S.E. Ireland.

Pteropoda.

HYALEIDÆ.

Theca, Sowerby, 1844.

Fam. *Hyaleidæ?*—Shell straight, sheath-shaped, triangular, compressed, without lateral appendages or spines of any kind. Mouth closed by a semicircular operculum, with the nucleus on the straight (dorsal) edge.

There are two groups of the shelled *Pteropods* known, one with straight or slightly curved shells and no operculum; the other with spirally rolled shells,

furnished with an operculum lobe, and, in *Spirialis* at least, with a shelly opercular plate.

To the former of these, from its analogous form, the palæozoic *Theca* and its allies have been always supposed to belong. No evidence has yet been published of shelly plates connected with these common shells, or with *Conularia* or its allies.

The fossil here figured, however, has constantly associated with it, and often in juxtaposition, a shelly plate which would just fit the aperture, and there can be no reasonable doubt that they belong to the shell, since they are found in plenty with it in the Shelve and Tremadoc districts. The *Theca* associated with it in the one case is a distinct species from that in the other, and this being so, it is probable that other species of the genus may possess a similar covering plate.*

It is not unworthy of remark, that the bulk of the recent *Pteropods* are without opercula, but *Theca* appears to have one, the case is similar with the recent forms of *Nucleobranchs* (*Heteropoda*), scarcely any of which have opercula, while the largest and thickest operculum known in the Silurian rocks belongs to an abnormal *Heteropod* genus,—*Maclurea*.

T. (*Cleidotheca*) *operculata*, Salt.

Pl. 10, figs. 22–24.

Short-conical, apical angle about 25°, with a compressed section; the dorsal surface nearly flat, projecting a little beyond the ventral, which is convex. No regular longitudinal ridges or furrows occur upon the shell, and the surface is remarkably even, except for the strong, sharp, curved lines of growth that cross it.

Operculum, a semicircular plate, abruptly bent, parallel to and near the straight margin. The larger area is a very wide and flat segment of a circle (almost a semicircle), divided from the narrow marginal area by deep wide furrows radiating from the nucleus, and partially bisected by a shallow furrow commencing from the same point. One or two radiating lines occur also near the furrows.

The bent portion of the plate is a narrow sub-triangular area, and is bisected, like the other and larger area, by a short central furrow.

The short proportions readily distinguish this species from the following, which occurs in equal plenty with it.

Locality.—Lower Tremadoc. Abundant in all the localities near Portmadoc, associated with large trilobites of two or three genera.

Theca penultima, Salt.

Brit. Assoc. Rep., 1865, p. 285, *ib.* Hicks. Quart. Journ. Geol. Soc., vol. xxviii., p. 180, t. 7, f. 15, 16.

This species occurs in the Grey Cambrian flaggy beds below the true Menevian, and also in Lingula flags. We only know it from the St. David's area.

Theca stiletto, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 180, t. 6, f. 18, 19.

Known only in the Menevian beds of St. David's.

Theca corrugata, Salt.

Quart. Journ. Geol. Soc., vol. xx., p. 238, t. 13, f. 10.

Formation and Locality.—Porth-y-Rhaw, St. David's.

Theca antiqua, Hicks.

Quart. Journ. Geol. Soc., vol. xxvii., p. 400, t. 16, f. 13. 1871.

Formation and Locality.—Longmynd Rocks, St. David's.

* Since this was written M. de Barrande asserts that he has long had several species of *Theca* in his Bohemian collection with opercula, and in some cases actually attached to the shell. It may be a generic character, but I retain the sub-genus for the present.

Theca bijugosa, Salt.

Pl. 10, figs. 19, 20.

Elongate (apical angle about 10° or 12°), the dorsal side convex, and ridged by three distinct keels—the central one of which is strongest—from the apex to near the mouth; the others faint at their origin, but becoming stronger near the aperture. On the flatter side a corresponding furrow appears to exist, but we have very little evidence with regard to this surface. Lines of growth inconspicuous, but greatly arched, following the very prominent margin of the mouth on the dorsal view. All our specimens are views of the dorsal aspect, except one from the Upper Tremadoc slate, and that appears to have a corresponding deep furrow; but it may only be a deep impression made from the opposite surface.

Locality.—Lower Tremadoc, with the last. Upper Tremadoc, same district; one upper figure not numbered on the plate.

Theca arata, Salt.

Pl. 10, figs. 15 and 21, and possibly figs. 17, 18.

Conical, rather short, apical angle about 15°, dorsal surface flattened, but with a raised central keel, on each side of which are one or two furrows. The lines of growth on this surface are very strongly arched; the mouth projecting a good deal. They are also prominent as raised threads, and almost rugose, much more so than in the last species. The ventral plate appears to be slightly concave, and the striæ are a good deal arched forward and equally rugose with those on the opposite surface.

Locality.—Lower Tremadoc, near Penforma Church, Tremadoc.

A variety? with similar dorsal keel and furrows, but smooth, or with only faint lines of growth, occurs in the Upper Tremadoc, Penyclogwyn and Tuhwnt-yr-bwlch, both near Portmadoc.

Theca Davidii, Hicks.

Quart. Journ. Geol. Soc., vol. xxix., p. 50, t. 3, f. 28, 29.

Formation and Locality.—Tremadoc. Ramsay Island and St. David's.

Theca simplex, Salt.

Pl. 11 B., figs. 22–26.

An inch and a quarter long, and one quarter broad, triangular in section; the dorsal surface nearly plane, a little convex, quite smooth, and with a gently arched mouth-margin. The ventral surface highly convex, with a few longitudinal lines, but no ridges, and crossed by direct lines of growth only. The mouth is frequently a little expanded. The operculum occurs in company.

There are not many characters to distinguish this species; but it is clearly not the same as the Upper Silurian *T. Forbesii*, being much more highly convex on the ventral side, and flatter on the opposite side, besides being of a much longer shape.

Locality.—Arenig. White Grit mine, Shelve, abundant.

Theca vaginula, Salt.

Pl. 10, fig. 14. It should have been in pl. 11 B.

Short-triangular, pointed, almost acuminate, ventral? surface very convex, bluntly angular along the central line, and with a narrow marginal rim. Dorsal surface flat? Edge of mouth?

It was premature to name this small species from a single specimen. But there are several specimens of apparently the same form in the Lower Llandeilo rocks of Shelve, and they do not agree quite with any of the Tremadoc species here described.

Locality.—Arenig.—Tai-hirion, near Arenig-fach, on the Bala road.

Theca caeresiensis, Hicks.

Quart. Journ. Geol. Soc. vol. xxxi., p. 189, t. 11, f. 7.

Formation and Locality.—Upper Arenig. Llanvirn Quarry.

Theca Harknessi, Hicks.

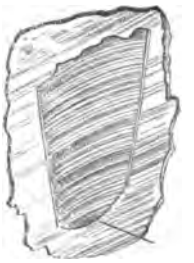
Quart. Journ. Geol. Soc., vol. xxxi., p. 189, t. 10, f. 7; *ib.*, Camb. Cat., p. 24 (undescribed there).

Formation and Locality.—Upper Arenig. Whitesand Bay, St. David's.

Theca obtusa, Salt.

Woodcut 17.

Fig. 17.



Shell very thin, straight, rounded in section, tapering backwards, and with a blunt rounded termination, and with two marginal thickened lines (surface obscurely marked by short longitudinal striæ). Nearly one inch long, and half an inch broad above. It would be very rash to constitute a new genus from a single crushed specimen. This is certainly not an *Orthoceras*, for which it might have been mistaken in newer rocks. It is very thin, has apparently two thickened margins running to the angular lateral edges as in *Theca;* but its termination is rounded and blunt, instead of tapering to a fine point.

Believing, therefore, that it cannot be *Orthoceras*, and as none, except a *Theca*, has heretofore been found in Primordial rocks, it may be presumed to be a large species of that genus till better material shall occur.*

Locality.—Lower Lingula Flags, Maentwrog Waterfall. Presented by Mr. Ash to the Mus. Pract. Geol.

Sub. genus. *Centrotheca.*

Shell straight, sheath-shaped, triangular, or compressed; mouth with long curved lateral appendages.

T. (*Centroth.*) *cuspidata*, Salt.

Pl. 10, fig. 25.

Broad-conical, the apical angle about 30°; the length about eight-tenths of an inch; the breadth, three-tenths. The (dorsal?) surface gently convex, a raised central area being more so than the rest, and this is marked with faint longitudinal ridges (three or four in one specimen, only a central ridge in another). The edge of the mouth is not greatly projecting in front, but it is thickened, and is produced on either side into a long curved spine. In one specimen this is four-tenths of an inch long.

Locality.—Upper Tremadoc Flag. Tu-hwnt-yr-bwlch, Portmadoc. (Presented by Mr. D. Homfray.)

Theca reversa, Salter.

Woodcut 14, fig. 6.

T. triangularis, Hall, Pal. New York; *T. reversa*, Salter in Siluria, 2nd ed., p. 550; Foss. 10, fig. 21.

A common species, which ought not to be confounded with the Upper Silurian shell (*T. Forbesii*), though much resembling it in shape and size; it only differs from that species, by having the dorsal plate convex. In *T. Forbesii* this is quite flat, and the front strongly angular. In this the dorsal surface is convex, and the ventral less angular. With the greatly elongated *T. triangularis* there is but little affinity.

* Better specimens have since been found by Mr. Homfray; near Tafarn helig, S. of Maentwrog.

Not an inch long, one-third of an inch wide at top, and rather quickly tapering. Dorsal surface gently convex, its front margin much projecting. The ventral surface angular, but not sharply so. Lines of growth very indistinct.

A pair of faint elevations are seen running lengthwise down the back, and in one specimen (interior cast) an internal thickened ridge runs along each side a little way from the margin. This ridge is common to several species.

Localities.—CARADOC.—North Wales; Horderley, Shropshire; S. Scotland; Bird's Hill, Llandeilo, South Wales.

Genus *Pterotheca*. Shell transversely oval, bilobed, with wavy sides and a strong median keel. Ventral plate short, narrow, and flat (*see* Siluria, 2nd ed., Foss. 39, fig. 4).

Cyrtotheca, Salter.

Cyrtotheca hamula, Hicks.

Quart. Journ. Geol. Soc., vol. xxviii., p. 179, t. 7, f. 14.

The only species of this genus, and one of the earliest *Pteropods* known, associated with *Stenotheca* and *Theca;* its only horizon and locality is the Menevian group, St. David's. *Theca penultima* appears to have been found in the very flaggy beds of the Cambrian group above the Upper Red series at St. David's. Menevian.

Stenotheca, Salter, 1866.

Stenotheca cornucopia, Salter.

Quart. Journ. Geol. Soc., vol. xxviii., p. 130, t. 7, f. 12, 13.

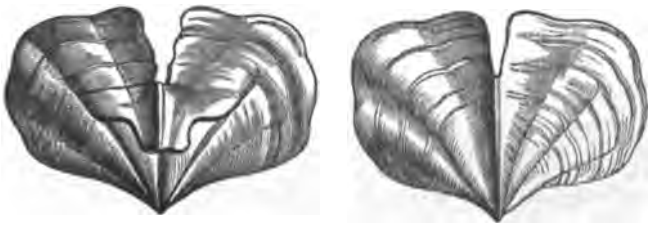
Like the last, only one species is known, and the genus occurs in the Menevian and Lingula flags of St. David's.

Pterotheca, Salter, 1852.

Pterotheca corrugata, Salter.

Brit. Assoc. Reports, 1852,—Trans. Sect., p. 61; Siluria, 2nd edit., p. 550.

Fig. 18.



P. lata, undulata, margine repando. Carina dorsalis valde elevata. Apiculus minutus.

The fine fossil, originally described in the British Association Reports along with the typical species, has only as yet occurred in one locality. It is abundant there, and shows casts of both back and front, as well as the triangular plate which encloses the visceral cavity. The extent to which the sides or wings expand is remarkable, very much greater than in any other genus now living. Such marginal expansions in one form or another are, however, not uncommon among the *Pteropoda* and *Heteropoda*. Barrande now finds the genus in Bohemia, and Hall in North America.

Width, 1½ inch; length, nine-tenths of an inch. The form is wi[illegible] verse, deeply notched in front, and marked by five broad undula[illegible] reach from the beak to the margin, causing a wavy outline. Th[illegible] tions are crossed by other waves in the direction of the lines o[illegible] that the whole shell is rugose. The dorsal plate is strongly cu[illegible] boat-shaped, and has a strong median elevated keel, reaching al[illegible]

the minute beak, and probably (but it is broken off) to the upper front margin. The lines of growth meet this keel everywhere at a right angle, and are not deflected by it. The small ventral plate is perhaps quite flat, but in one much-squeezed specimen it has a central ridge corresponding to the dorsal keel; and this may be the real character. The plate is flat in he other species, one of which is Lower and the other Middle Silurian.

Locality.—CARADOC, Dolbenmaen, near Criccieth; several Nuculoid shells accompanied this (probably) deep-water form.

Conularia, Müller, 1818.

Conularia Llanvirnensis, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi, p. 189, t. 11, f. 5, 6.

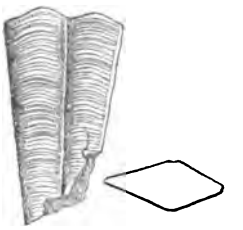
Of the nine species known, four occur in the Arenig rocks, the North Welsh form *C. Homfrayi* being also a Tremadoc species.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, near St. David's.

Conularia lævigata, n. sp.

Woodcut 19.

Fig. 19.



A compressed specimen, with a rhomboidal section; it tapers slowly at 15°, probably less, and is seven lines broad, and fully 1¾ inches long. The faces are flat or even a little convex, the two neighbouring ones which meet at one of the acute angles being rather broader than the other two. Surface nearly smooth; the lines of growth irregular in thickness, gently arched across each face, without being angularly bent in the middle. Furrows at the angles rather shallow.

The rhomboidal section may be the result of pressure, but it does not appear to be wholly due to it, and as the two smaller faces meet at one of the acute angles, and the two larger at the other, the shell is probably near its true form. On the smaller face the striæ seem to rise to a higher level towards the angle furrow than towards the lateral one, a character observable in some other compressed species.

The irregular and simply arched lines of growth distinguish this easily from *C. subtilis*, Salter. *C. elongata*, Portlock, has a strong median furrow on each face.

Locality.—CARADOC. Llwyn-yr-hwch, 3 miles south of Beddgelert, North Wales.

Conularia Homfrayi, n. sp.

Pl. 10, figs. 11–13.

C. tenuis, fere membranacea, magna, 4-5-uncialis, elongato-conica, quadrato-cylindrica, apice acuto; costis tenuibus longitudinalibus crebris, nullis transversis, ornata. Costæ in angulo quoque binæ, in faciebus 2-4 filiformes, interstitiis undulatis et rugatis. Lobi oris lanceolati-obtusi, membranacei, ecostati, haud conniventes.

Four inches and a half long, and three-quarters wide at the larger end, conical, with straight sides, sharp pointed apex, and double ridges, eight in number. No distinct transverse rugæ are present, but the surface is a little

rugate or puckered between the ridges. These ridges occur at each angle between the faces, and there are two, three, or more along the middle of each face; the lobes of the mouth are broad-pointed and tongue-shaped in front and behind, shortest on the sides, and not bent inward or contracted as in kindred species.

The nearest ally of this fine shell, unexpectedly met with so low down in the Protozoic series, is an unpublished species in the Ludlow rocks of Shropshire. It is somewhat larger than this, broader in outline, and has the ridges along the middle of each face, but not along the furrows between the faces. It differs still more markedly in having the mouth contracted; and all the lobes bend inward towards one another, so as partially to close the mouth in the adult form. Very probably these two and other allied species will constitute a distinct genus, when we know enough of these old *Pteropods* to classify them more completely.

Locality.—Upper Tremadoc. Garth Hill, abundant; Tu-hwnt-yr-bwlch. Collected by Messrs. Ash and D. Homfray, of Portmadoc. The figured specimens are from the cabinet of Mr. Homfray, and from the Woodwardian Museum, Cambridge. [Also M. P. G.]

Conularia margaritifera, Salter.

Pl. 11 A., fig. 12.

C. modica, segmentis (uno solùm conservato) planis? striis transversis valde obliquis, ut S. curvis, tuberculis minutis longitudinalibus ornata. Sulcus subcentralis.

A small species, apparently with a thin shell. We have only a fragment of one segment, and that is covered by regular, rather imbricating striæ, which run very obliquely across in a sigmoid curve. Fine longitudinal striæ, scarcely to be called tubercles, are easily traceable on the ridges, but they do not cross the intervening hollows. The sulcus is subcentral, and very little interrupts the course of the ridges.

We know of no species that can be well compared with this; the sigmoid ridges easily distinguishing it from all the Silurian forms known; for comparison with other forms of the genus, see Dr. Sandberger's paper in the Neues Jahrbuch for 1857, pl. 1.

Our species is a true *Conularia*, not a *Coleoprion*, as may be seen by the central line.

Locality.—Arenig. Ty-obry, near Garth, Tremadoc.

Conularia Corium, Salter.

Pl. 11 A., fig. 11.

C. fere pedalis, lævis (quasi coriacea), quadrato-cylindrica, angulis vix (nisi ad orem) prominulis; sulci angulorum facierumque æquales, angusti; striæ transversæ nullæ.

Nine or ten inches long, at least one and a quarter broad, and slowly tapering; sub-cylindrical in section below, sub-quadrate above, with sharp narrow continuous furrows at the angles, and somewhat interrupted ones in the middle of the faces. At about half the length the angles begin to grow a little prominent, and thence continue more and more prominent to the mouth. The furrows on the faces are in parts less continuous, lie nearly in the middle of the faces, and only near the mouth are elevated upon ridges. They are flanked by two fainter ones for some distance from the mouth. The shell is not contracted or lobed at the mouth, as in *C. Homfrayi*, nor is the substance, which seems to have been coriaceous throughout, thinner or more membranous at this part.

No transverse striæ or ribs of any kind are visible, and the whole shell has a smooth surface, and is so much bent as to give the idea of its having been of a flexible material, rather than a rigid shell.

Mr. Salter did not feel sure it was distinct from the great *C.* [illegible] the May sandstone, Normandy. Fine specimens are in [illegible] Society.

Locality.—Arenig. Ty-obry, Penrhyn; near Tremadoc. [illegible] were found by our collector, Mr. R. Gibbs.

Cephalopoda.

ORTHOCERATIDÆ.

Orthoceras, Breynius, 1732.

Orthoceras encrinale, Salter.

Pl. 11 B., fig. 20.

Siluria, 2nd ed., p. 50, Foss. 8, fig. 10.

Some inches long, and less than half an inch broad. Cylindric, closely annulated by somewhat oblique prominent rings; which are rounded, not keeled, or imbricate, or marked by striæ of growth (at least in the inner cast), and as broad as the rounded interspaces.

This is an older portion; when the diameter is only one-third of an inch, the rings are sharper edged, not so broad as the interstices, and often wavy, and show some traces of intermediate wavy striæ. The shell may have been covered with such markings outside, and in that case would have a considerable affinity to the group of *O. annulatum*.

Locality.—ARENIG. Cefn Gwnylle Mine, Shelve, Shropshire. (Mus. Pract. Geology.)

Orthoceras caereesiense, Hicks.

Quart. Journ. Geol. Soc., vol. xxxi., p. 189, t. 11, f. 8–10.

Of the 44 species known in this genus from the Silurian Rocks of Britain, one only is Tremadoc (*O. sericeum*, Salt.), four of Arenig age, and two of them from the Shelve country W. of the Stiper stones, *O. encrinale*, Salt., and *O. Avelini*, Salt.

Formation and Locality.—UPPER ARENIG. Llanvirn Quarry, St. David's.

Orthoceras Avelinii, Salter.

Pl. 11 B., fig. 18.

Siluria, 2nd ed., p. 50, Foss. 8, fig. 4.

A common species, seldom found of more than three-quarters of an inch broad, and which must have measured about six inches in length. Section round. Siphon excentric, placed one-third the whole diameter from the margin, small. Septa flattened, very little oblique, two in the length of a diameter where the shell is half an inch broad. Shell rather thin, strongly striated direct across, except a slight downward wave on the opposite side to the siphon; the striæ coarse, imbricating forwards, and sometimes interlined irregularly.

The tube is quite cylindrical and even for all its older portion. But the young shell is slightly annulated in the direction of the septa, and the projection is along the line of the septum, the shell being contracted between each.

This may possibly be only a variation in individuals, but the character is worth notice. The species is allied to *O. subundulatum* and the other thin-shelled striate species, so common in the Silurian rocks.

Locality.—ARENIG. Cefn Gwynlle Mine, Shelve. Collected by Mr. Gibbs. The species is named after Mr W. Talbot Aveline.

Orthoceras sericeum, Salter.

Pl. 10, figs. 4, 5.

Probably 10 inches to a foot in length, but not above three-quarters of an inch broad, surface marked only by transverse (oblique?) lines of growth, which are not prominent, but rise into more conspicuous ridges at short intervals, particularly near the mouth.

The septa are remarkably numerous and close, in fig. *a* pressed laterally and therefore a little lengthened. There are 19 in the space of an inch. In fig. *b*, which is somewhat shortened by pressure, there are 20 in an inch. As they are oblique in all the specimens, it is fair to suppose them really oblique to the axis of the shell, but how much so it is impossible to say. The siphon Salter examined. It is very large, and a good deal excentric, but not quite lateral.

In the very close septa, and somewhat rugose character of the terminal portion, this differs from any Lower Silurian species with which to compare it.

Locality.—Upper Tremadoc. Garth: all the figures are from Mr. Homfray's cabinet.

Orthoceras vagans, Salter.

Pl. 24, figs. 1–5.

Quart. Geol. Journal, vol. 5, pl. 6, fig. 6. Siluria, 2nd ed., p. 219. Foss. 40, fig. 1.

One of the very few fossils common to the British and central European areas. Except this rather remarkable species, and the still more widely diffused *Bellerophon bilobatus*, we hardly know a fossil common to the Lower Silurian beds of the two areas. The trilobites, gasteropoda, and even most of the *Brachiopods*, are all distinct in the Lower Silurian period; while many species are identical in the Upper Silurian in the two regions. (Barrande, *passim.*)

The species grows to a large size; specimens 1¼ inches broad occur, and as the species tapers very slowly, this indicates a length of at least 18 or 20 inches. It is smooth, tapers very gradually in youth and mid-age, but is more conical when old. The septa are broad elliptic, oblique on the longer axis, moderately distant in the young shell, more than their diameter apart in middle age, and less than one-fourth their diameter apart when old. They are deeply cup-shaped, and the siphon is as nearly central as possible. The last chamber is unusually long. The remote septa, and broad oval, instead of round section, while the siphon keeps a central place, easily distinguishes this common smooth species from other Silurian shells. It were to be wished all described fossil *Orthocerata* had as good claims to specific distinction. But they generally sadly puzzle the describer.

Localities.—Caradoc. Rhiwlas and other places near Bala; Coniston limestone of Westmoreland.

Orthoceras, sp.

Pl. 24, fig. 6.

It is unsafe to name so imperfect a fragment. Yet the species is noteworthy, as being a large one, probably 15 inches long, of quite circular form, and with a thick shell. The septa are only moderately distant.

Locality.—Caradoc. Rhiwlas, Bala.

Orthoceras audax, Salt.

Pl. 24, fig. 7.

Probably three inches long, and half an inch broad (last chamber lost). Section broad oval. Siphon? Septa nearly direct, equidistant, close set, 6–7 in the space of a diameter.

Our figure represents the septa too oblique. They are nearly direct across.

O. gregarium of M'Coy's Lower Silurian Fossils of Ireland, from the same Bala limestone at the Chair of Kildare, appears to be the same species. It has an oval (not a subcircular) section, and it is certainly not the Upper Silurian fossil so called. [Synops. Sil. Foss. Ireland, p. 9, pl. 1, fig. 5.]

Locality.—Caradoc. Rhiwlas, Bala, a locality rich in deep-water forms.

Cyrtoceras Sonax, Salt.

Pl. 25, fig. 1.

C. magnum, subteres, lente curvum, striatum, striis asperis rectis, nonnullis prominulis. Septa modice approximata. Sipho magnus, internus.

A fine shell, rather abundant in the Rhiwlas limestone, Bala. It must have measured fully eight or nine inches when complete, and has a diameter at the mouth of 2½ inches by 2, the sides being compressed, and the section broad oval. The curve is gentle, the lines of growth nearly direct across, not arched downwards either on the back or front; they are somewhat roughly imbr but not regularly so. They are coarse raised threads, about eight in lines; and occasionally interrupted by somewhat more prominent ridges. septa are also nearly direct, but a little curved upwards towards the c dorsal margin. They are moderately convex, and about three lines dist

a diameter of 1½ inch. The siphuncle is large and placed close to the inner* border (fig. 1 *a*). The shell probably thin.

We have the means of completing (or nearly so) the form of this species, by reference to smaller specimens in the same locality. It is very slightly curved, compared with the next, and is besides less compressed.

Locality.—CARADOC.—Rhiwlas, Bala.

Cyrtoceras atramentarium, Salt.

Pl. 25, figs. 2, 3, 4.

C. medium, compressum (2×3), *curvum*, (*striatum?*) *Septa approximata, obliqua, curvata. Sipho internus.*

A smaller, much more curved, and more compressed fossil than the last. Its diameter front and back is rather more than 1½ inch, and from side to side one inch. The proportion therefore is as three to two. The section is nearly a true oval, scarcely so much narrowed on the back as in our figure, and the siphon, not very large, is nearly internal.

The sharp lines of growth (not plain in our specimens) curve much backward, while the septa curve forward toward the back. They are considerably more oblique than in *C. sonax*, and this is the more conspicuous from the stronger curve of the shell. Their course is nearly direct for a third across, then bent rather than curved, and passing obliquely forward to the dorsal margin. At one inch diameter there are seven septa to the inch on the outer margin; they are crowded on the inner edge. The last chamber appears to be about as long as broad, its margin oblique, following the lines of growth (in *C. sonax* it is direct).

Locality.—CARADOC. Bala.

Cyrtoceras præcox, Salt.

Pl. 10, fig. 3.

About an inch long, conical, gently curved, the mouth very oblique, the inner (dorsal?) margin being the prominent one. The septa, which follow the same curve, from within outwards, are placed very near together, four chambers in the space of one-tenth of an inch.

The shell was evidently a thin one. It is the earliest of the *Cephalopods* known, and it is not a little remarkable that the first species we meet with in ascending order should be—not *Orthoceras*, which is the most diffused and persistent form, but a genus which, so far as we know, is only Silurian and Devonian.

Locality.—LOWER? TREMADOC SLATE. Llanerch, W. of Portmadoc (Mr. Ash).

Lituites planorbiformis, Conrad.

Pl. 25, fig. 5.

See Appendix Pal. Foss. Woodw. Mus., p. 8, and M'Coy, *ib.*, p. 324.

The specimen figured is a small portion only, formerly found by Professor Sedgwick and Mr. Salter at Bala, and described at length by Professor M'Coy and himself. Better specimens since obtained show four or five smooth whorls.

Locality.—CARADOC. Cwm Cymmerig, Bala (fig. 5). Complete casts at Twll-du, above Cwm Idwal, in the upper beds, at the crest of the pass, between the trappean layers.

June 1865.

The time is not far distant when some attempt will be made to correlate the Welsh strata, through their fossils, with their equivalents in N. and S. America, Sweden, and Norway, Bohemia, France, and Spain, India and

* This is really the dorsal margin, as we learn from *Nautilus*, but the ordinary nomenclature gives the convex edge for the back.

Australia. The materials for such an essay are extant. Etage C of Barrande is equivalent to our Lingula flag; and Etage D to our Arenig, Llandeilo, and Caradoc series.

Mr. Salter regarded the Quebec group of Canada as equivalent to our Tremadoc and Arenig beds, and that the Regio BC of Angelin corresponds very nearly to the same horizon. The comparisons by Barrande, now so actively resumed by that admirable paleontologist, will give closer insight into the real relations of the lower beds of the Bohemian basin with our own. His great works upon the Silurian Trilobita Cephalopoda, and Brachiopoda have already greatly aided us in attempting to correlate the Silurian species of Britain with those occurring in the classical area in Bohemia, and during the past ten years Hall, Meek and Worthen, Billings and Dana, of America, Angelin, Lindstrom, Schmidt and Linnarsson in Scandinavia, with Hicks, Salter, McCoy, Davidson, in Britain, seem to have almost exhausted the fossil contents of the oldest rocks known to man.

J. W. S.
and
R. E.

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PLATE 1.

LINGULA BEDS.

Tracks made by Hymenocaris vermicauda (Tremadoc N. Wales).

Geological Survey of the United Kingdom. LINGULA BEDS.

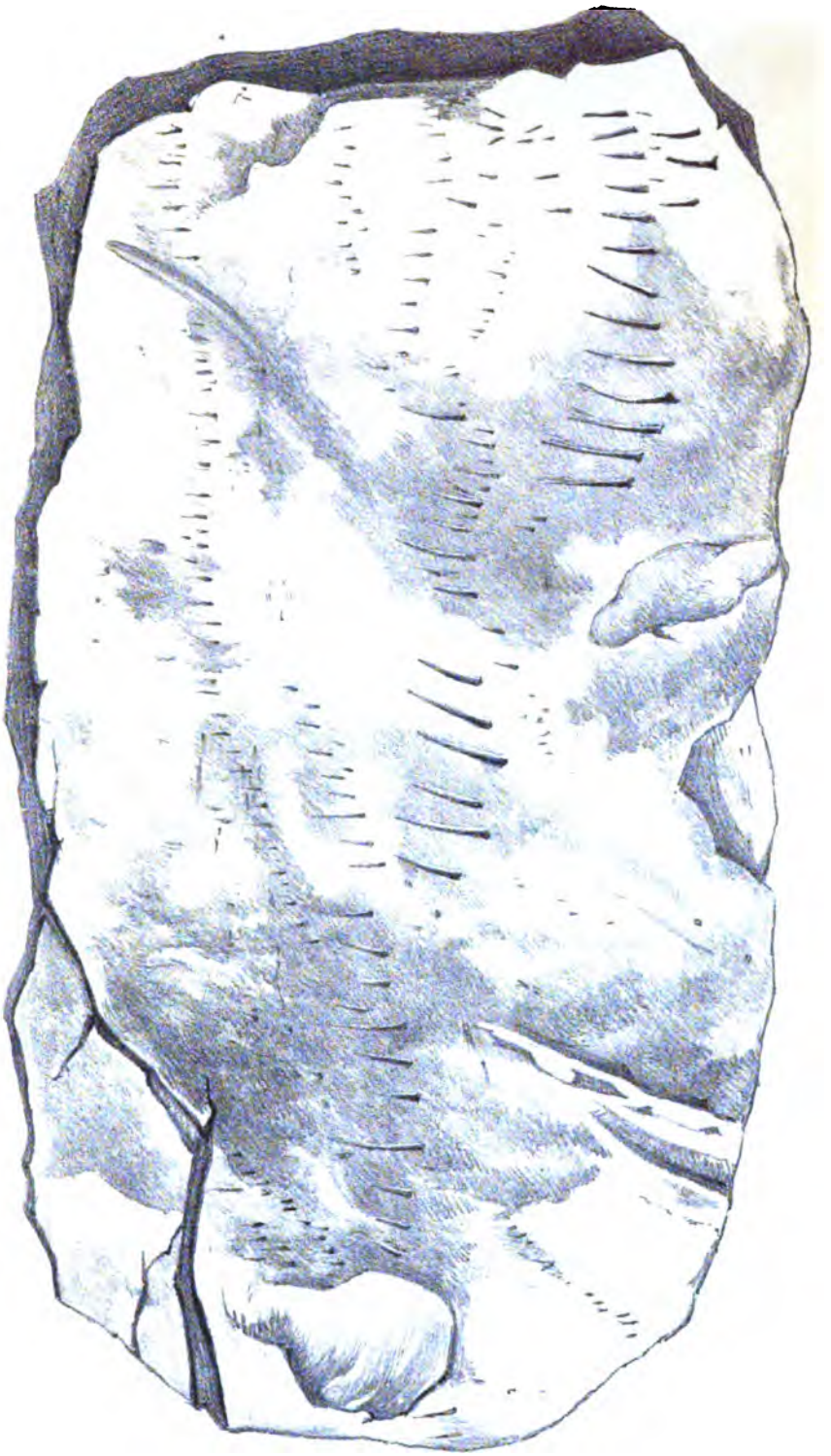

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PLATE 2.

LINGULA BEDS.

Hymenocaris vermicauda, Salter; figs. 1–4.
Olenus micrurus, Salter; figs. 5, 6.
Lingulella Davisii, M'Coy; figs. 7–12.

Geological Survey of the United Kingdom.

PLATE 2

LINGULA BEDS.

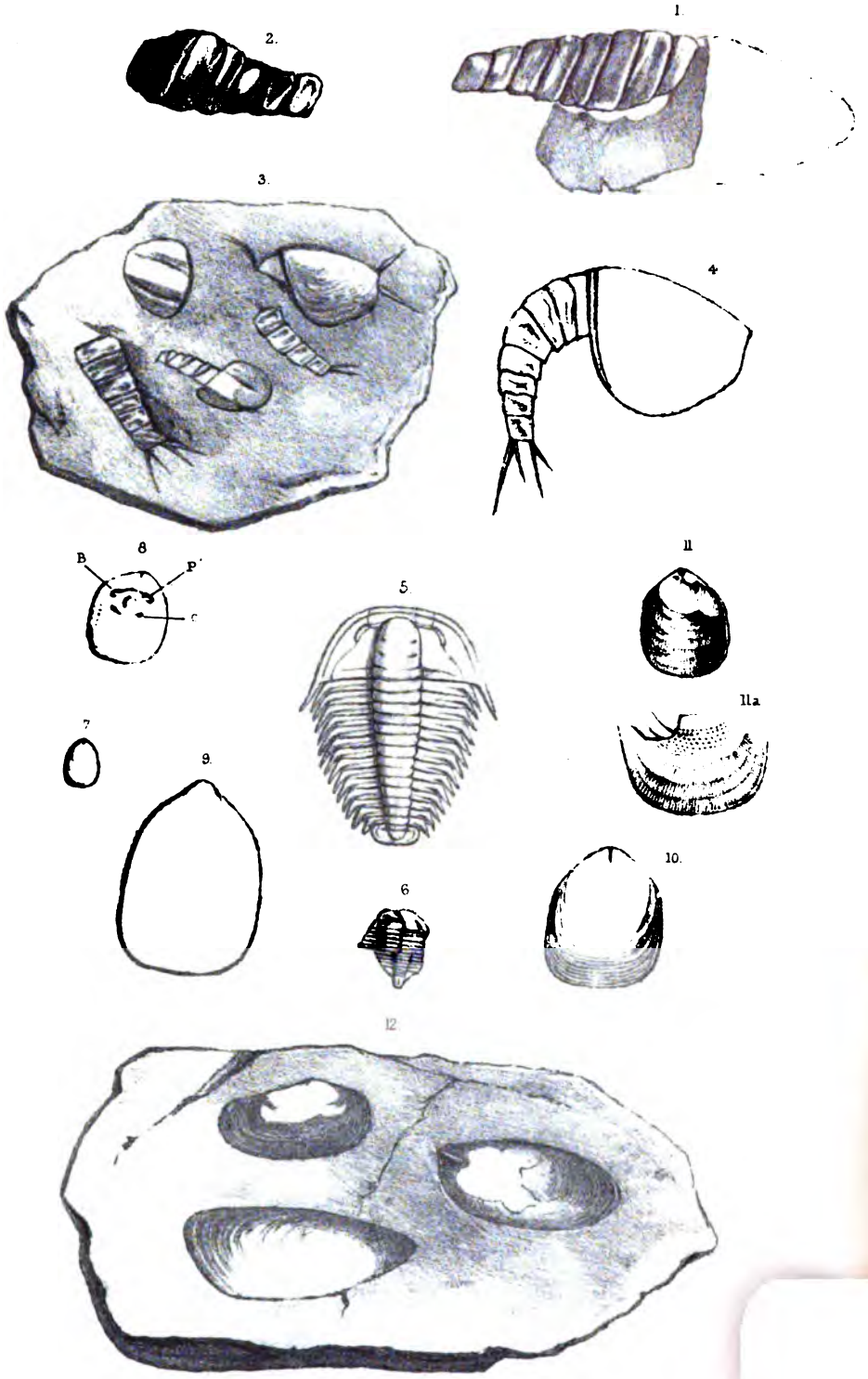

PLATE 3.

LINGULA BEDS.

Cruziana semiplicata, Salter; figs. 1–3.
Annelide burrows; fig. 4.

N 261. 500.—6/82. Wt. 14098.

3.
2.
1.
4

PLATE 4.

LINGULA FLAGS.

Dictyonema sociale, Salter; fig. 1.
Agnostus princeps, Salter; figs. 2–11.
Olenus alatus, Boeck; figs. 3, 4.
Conocoryphe invita, Salter; figs. 5–7.
Orthis lenticularis, Dalm.; figs. 8–10.
Paradoxides Forchammeri? Hicksii, Salt.; fig. 12.
Annelide burrows; fig. 13.
Lingulella Davisii, M'Coy; fig. 14.

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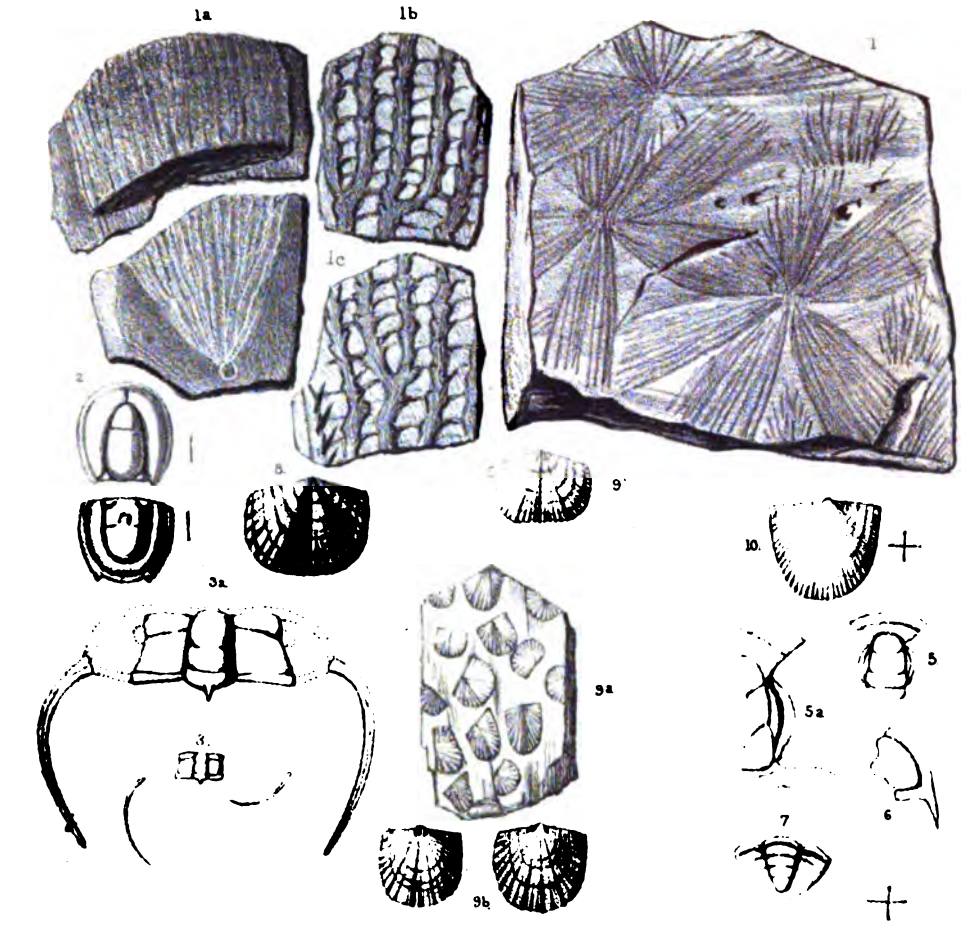
PLATE 4.
LINGULA FLAGS.



UPPER LINGULA FLAGS.

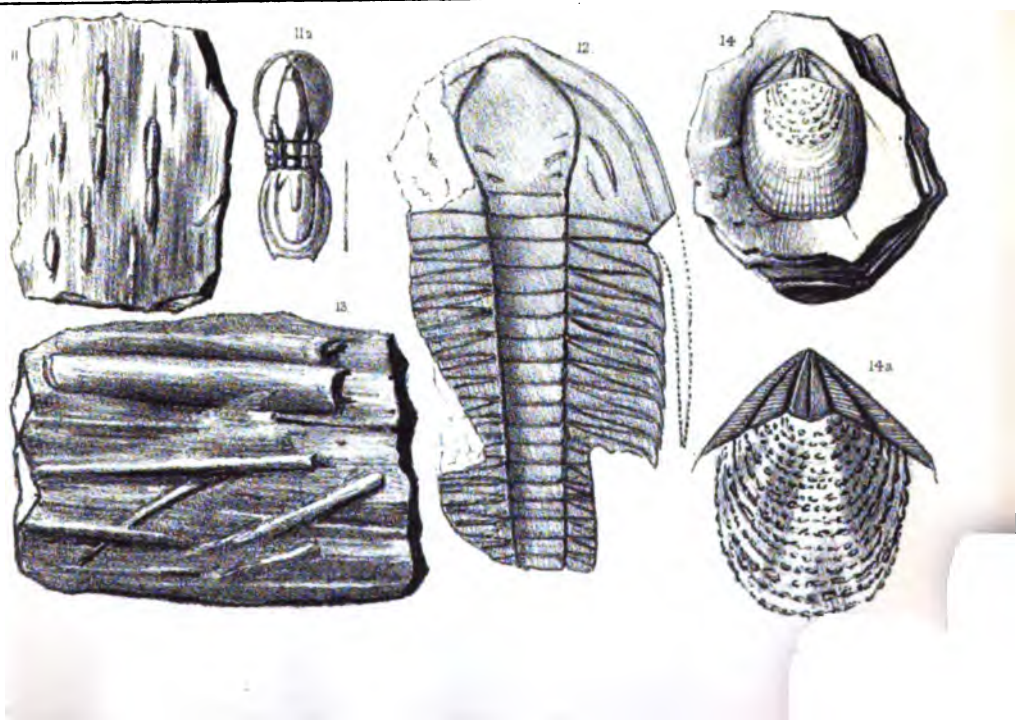
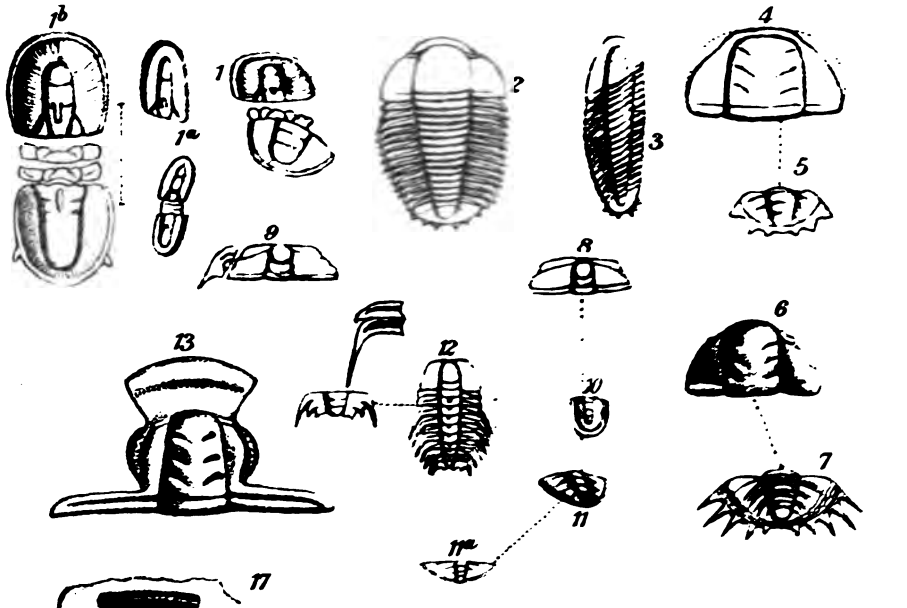


PLATE 5.

LINGULA FLAGS.

Agnostus princeps, Salter ; fig. 1.
Oleni, various species ; figs. 2–12.
Conocoryphe, ——; figs. 13–16.
Conocoryphe? simplex, Salter; fig. 17.
Dikelocephalus? ; figs. 18–22.
Olenus cataractes, Salter ; fig. 23.
Scolecoderma? tuberculata, n. sp. ; fig. 24.
Hymenocaris vermicauda, Salt. ; fig. 25.



LOWER LINCULA FLAGS

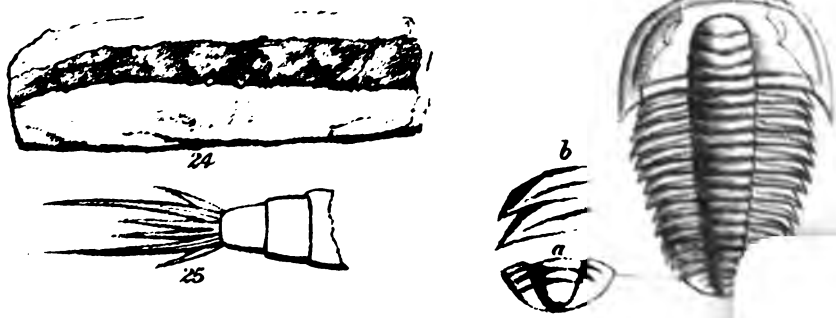


PLATE 6.

LOWER TREMADOC.

Conocoryphe depressa, Salter; figs. 1–3.
Dikelocephalus furca? Salter; fig. 4.
Niobe Homfrayi, Salter; figs. 5–8.
Psilocephalus innotatus, Salter; figs. 9–12.
Conocoryphe verisimilis, Salter; fig. 13.

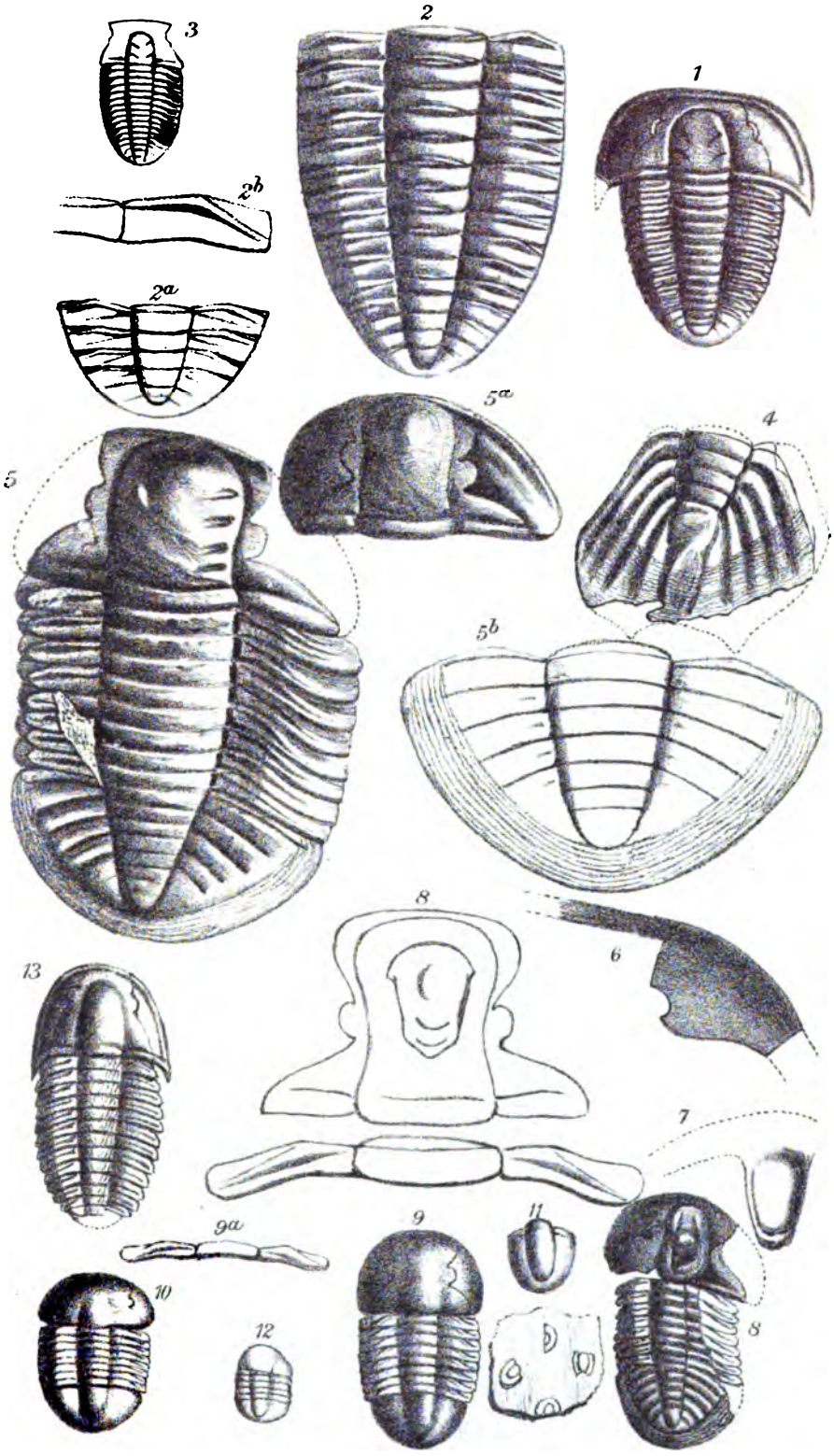


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PLATE 7.

TREMADOC SLATES.

Angelina Sedgwickii, Salter; figs. 1–5.
Conocoryphe invita, Salter; fig. 6.

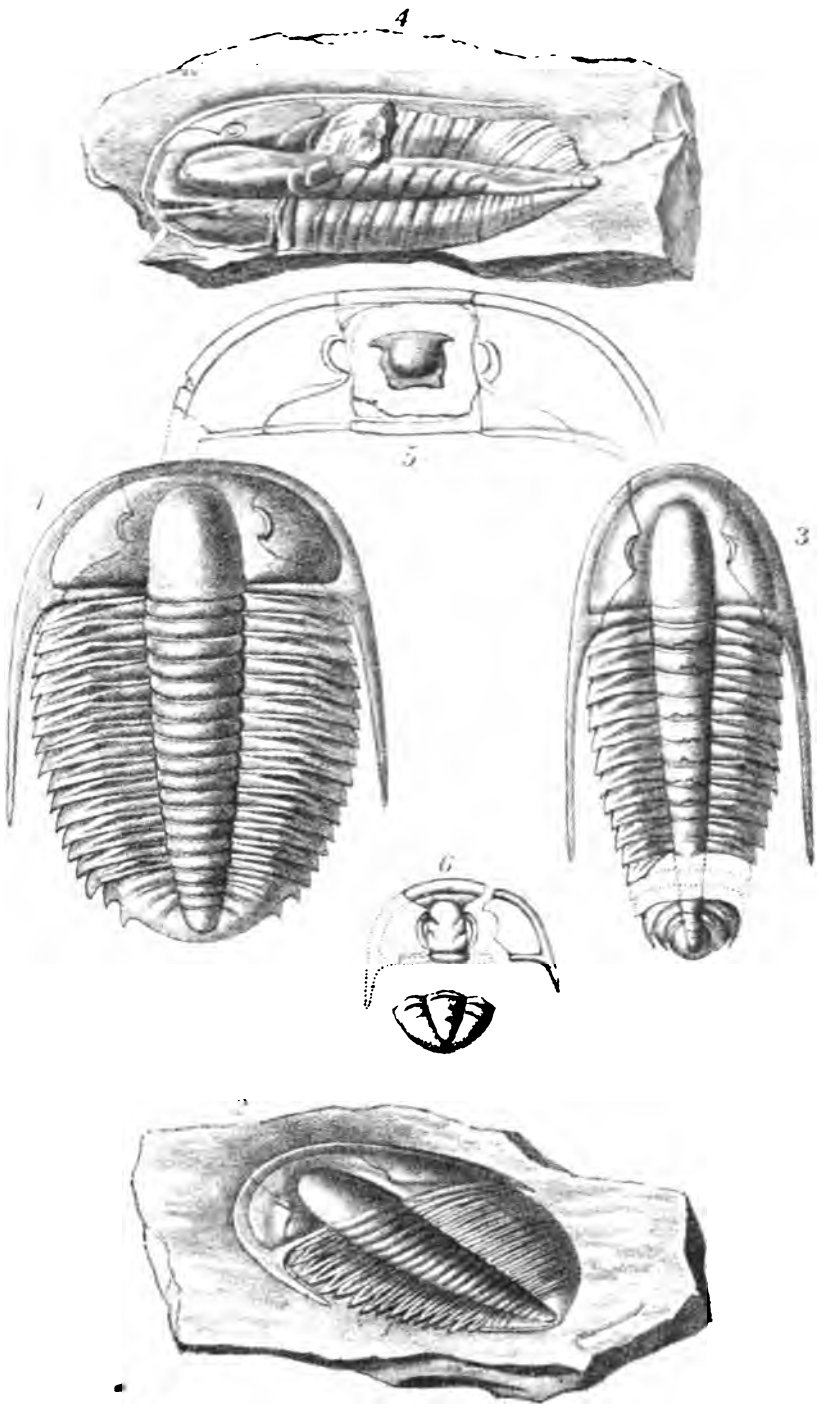

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PLATE 8.

UPPER TREMADOC.

Cheirurus Frederici, Salter; figs. 1–3.
Olenus impar, Salter; fig. 4.
Ampyx prænuntius, Salter; fig. 5.
Conocoryphe olenoides, Salter; fig. 6.
„ vexata, Salter; fig. 7.
Ogygia scutatrix, Salter; fig. 8.
Dikelocephalus furca, Salter; figs. 9, 10.
Asaphus Homfrayi, Salter; figs. 11–14.
„ affinis, M'Coy; fig. 15.

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PLATE 8
(UPPER TREMADOC)
(PART ARENIG)

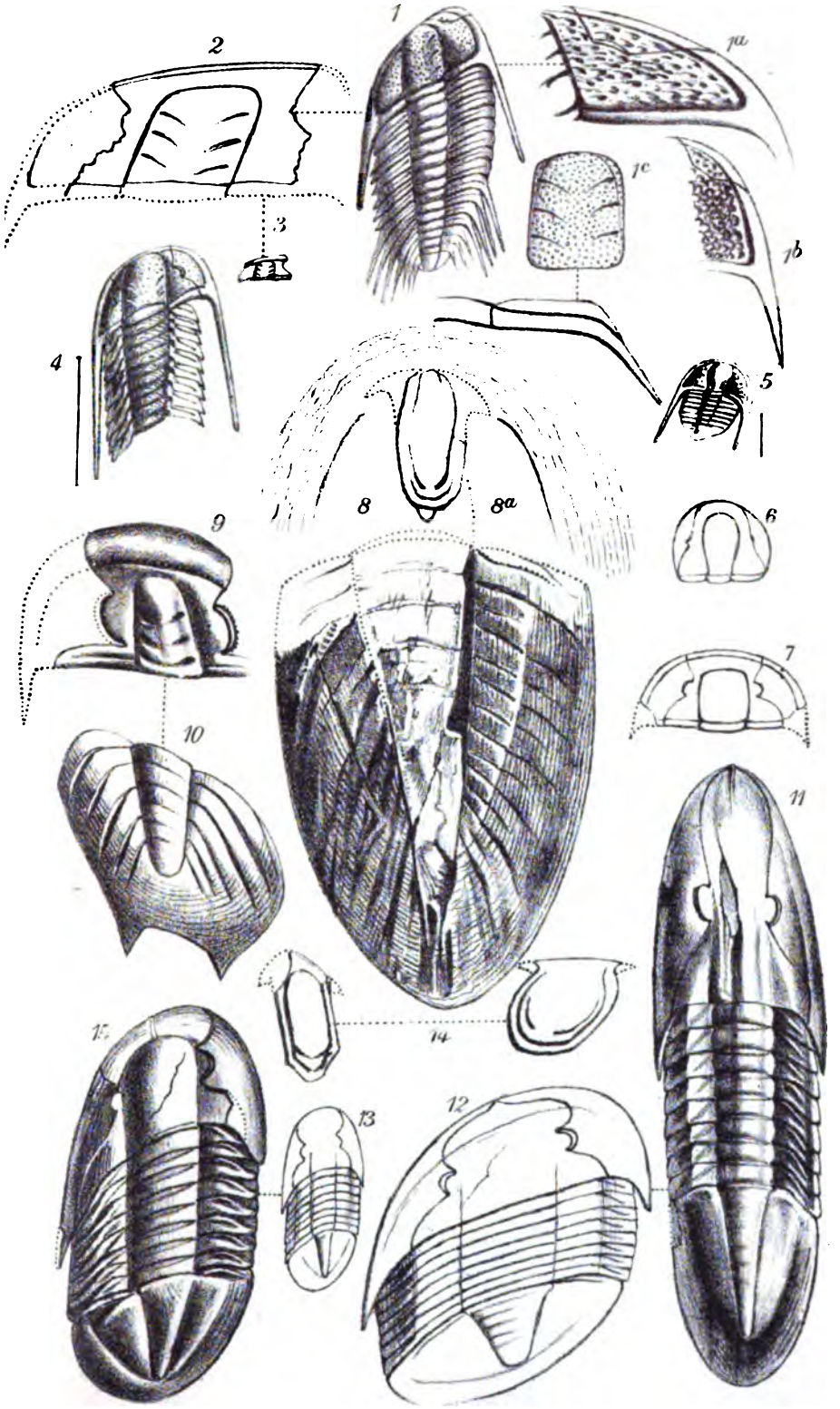

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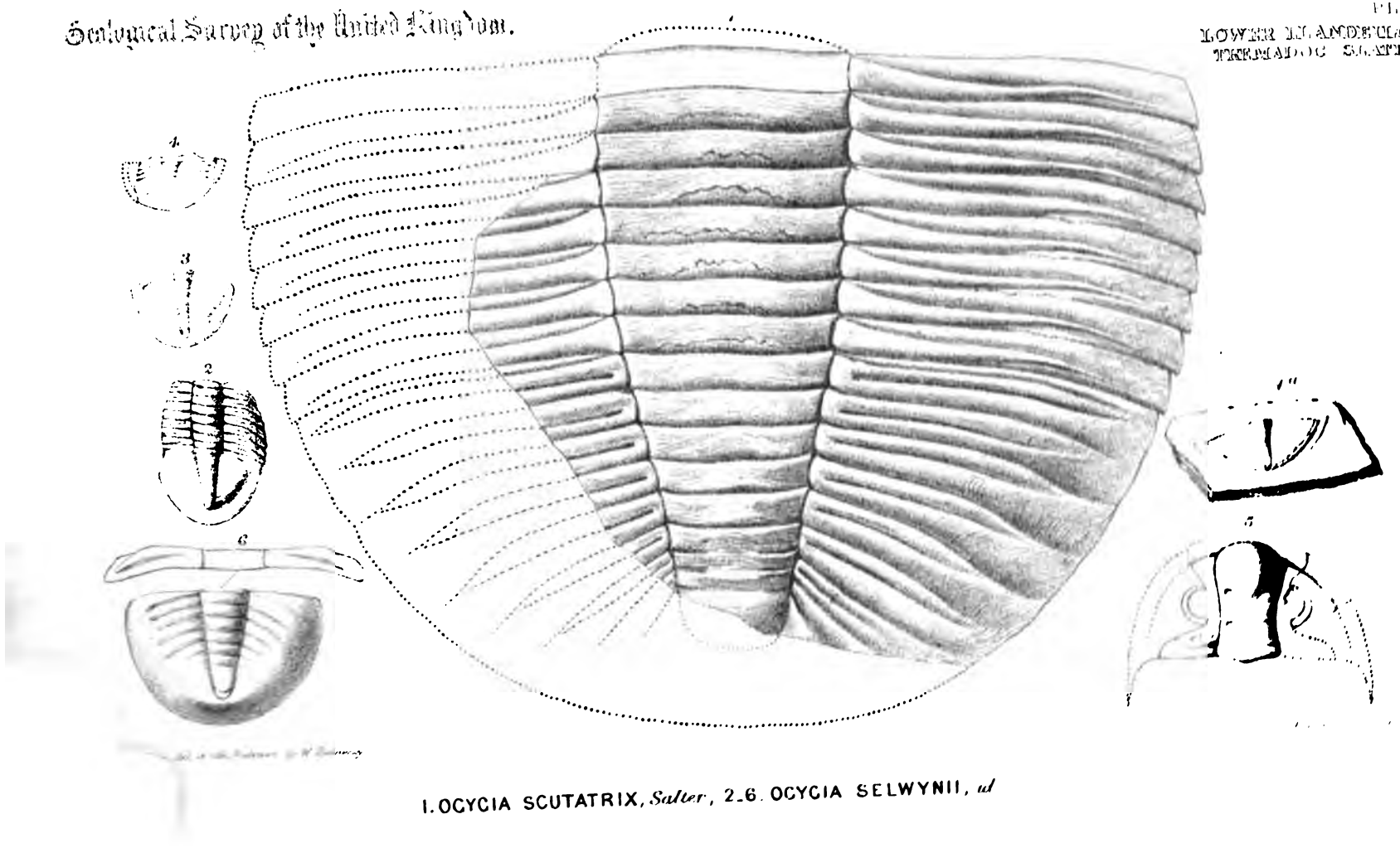
PLATE 9.

LOWER LLANDEILO, OR TREMADOC SLATES.

Ogygia scutatrix, Salter; fig. 1.
„ Selwynii, Salter; figs. 2–6.



1. OCYCIA SCUTATRIX, *Salter*, 2-6. OCYCIA SELWYNII, *id*

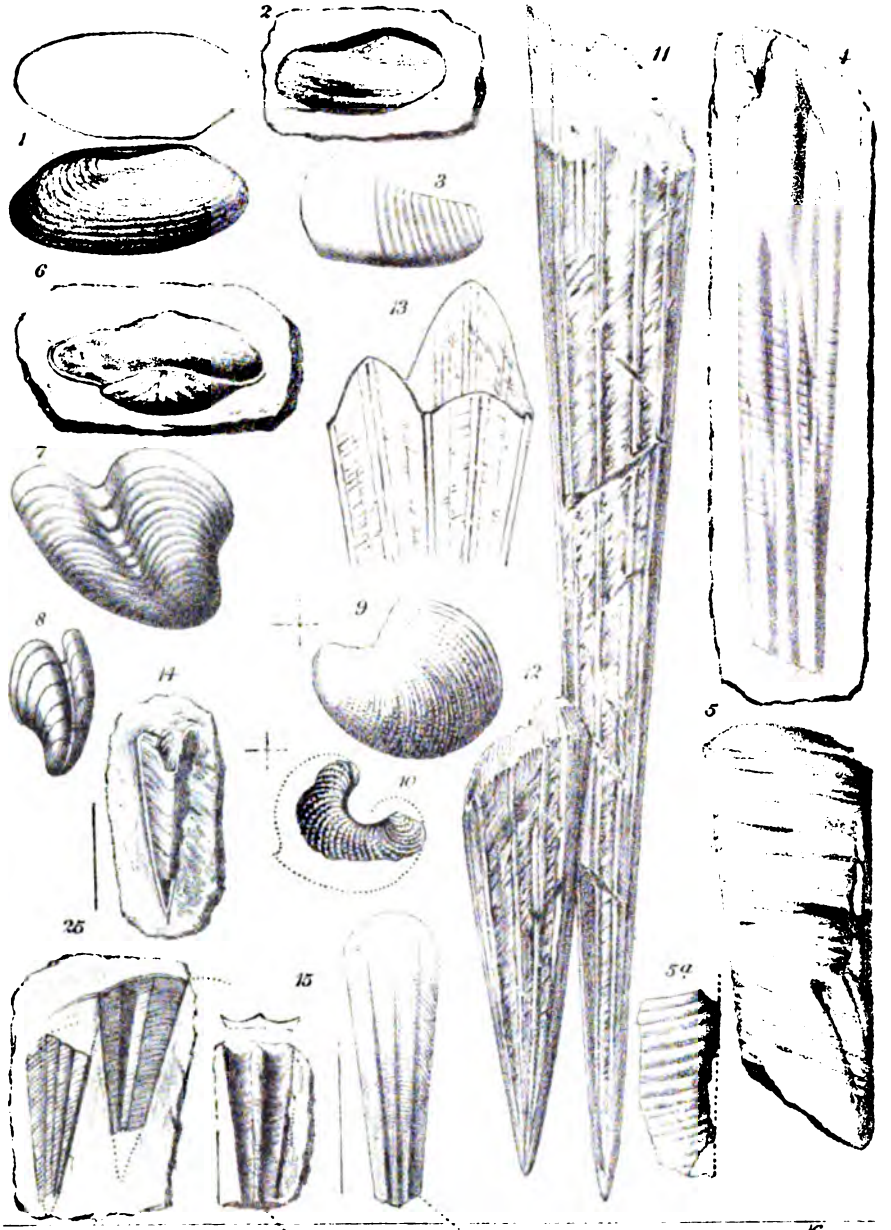
PLATE 10.

UPPER TREMADOC SLATE.

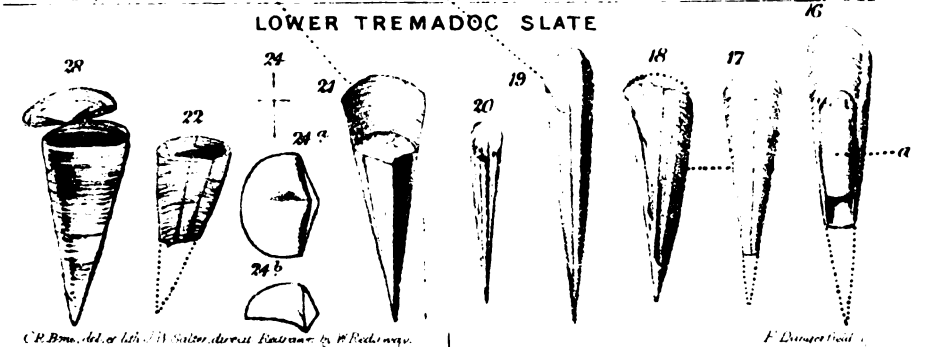
Lingulocaris lingulæcomes, Salter; figs. 1, 2.
Cyrtoceras præcox, Salter; fig. 3.
Orthoceras sericeum, Salter; figs. 4, 5.
Bellerophon; figs. 6–10.
Conularia Homfrayi, Salter; figs. 11–13.
Theca, three new species; figs. 14–21.
„ (Cleidotheca) operculata, Salter; figs. 22–24.
„ (Centrotheca) cuspidata, Salter; fig. 25.

Geological Survey of the United Kingdom. (TREMADOC SLATE)

UPPER TREMADOC SLATE.



LOWER TREMADOC SLATE



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1. 2. LINGULOCARIS LINGULOECOMES *n. sp.*
3. CYRTOCERAS PRŒCOX *n. sp.*
4. 5 ORTHOCERAS SERICEUM *n. sp.*

11-13. CONULARIA HOMFRAYI *n. sp.*
14-21. THECA *3 new sp.*
22. 24. THECA (CLEIDOTHECA) OPERCULATA *n.*

PLATE 11A.

LOWER LLANDEILO.

Diplograptus, various sp.; figs. 1–3, 4–6.
Dendrograptus furcatula, Salter; fig. 5.
Agnostus; fig. 7.
Homalonotus bisulcatus, Salter; fig. 8.
Dionide atra, Salter; fig. 9.
Æglina caliginosa, Salter; fig. 13.
Conularia, two species; figs. 11, 12.
Palæarca socialis, Salter; fig. 13.

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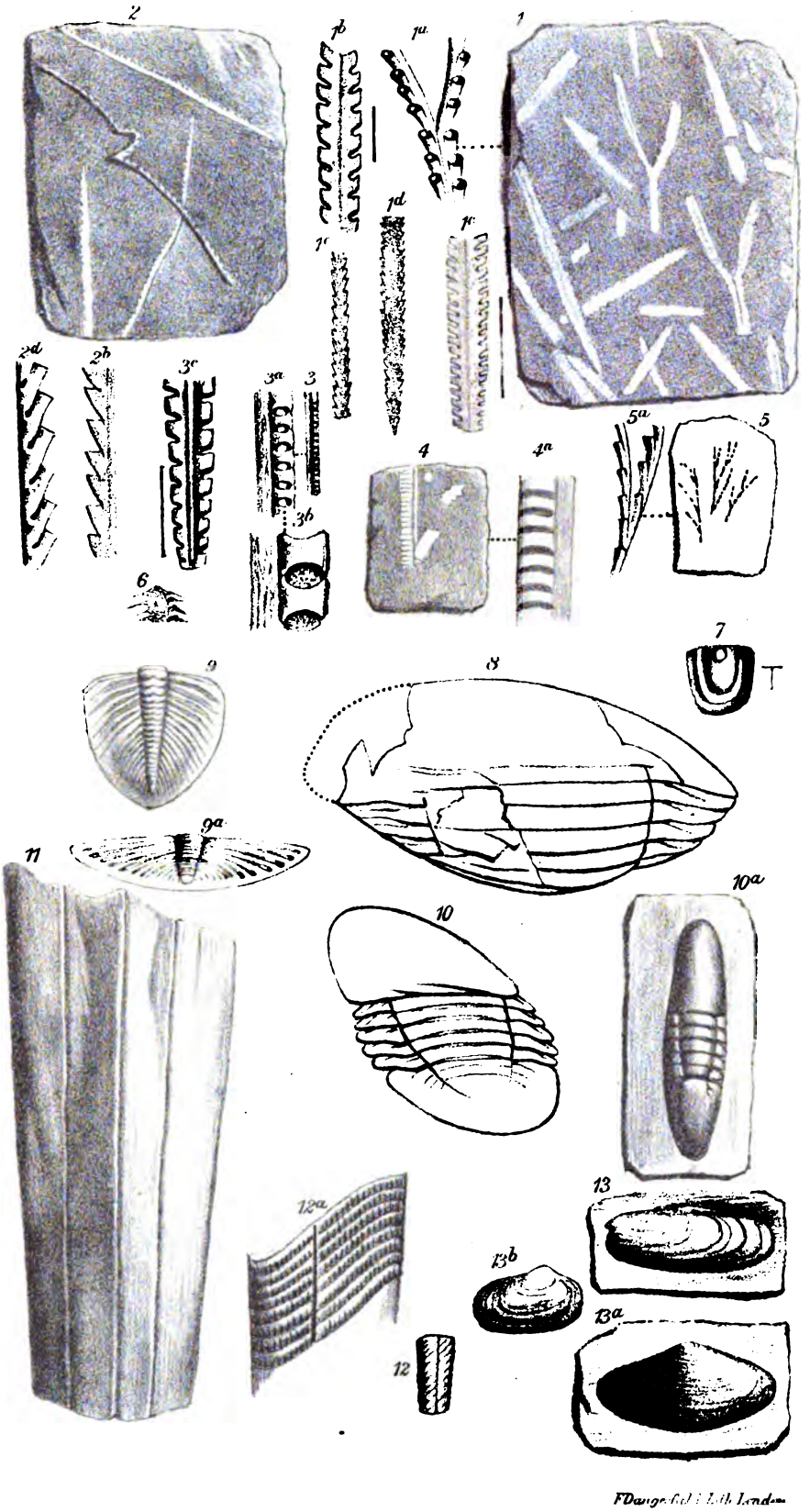

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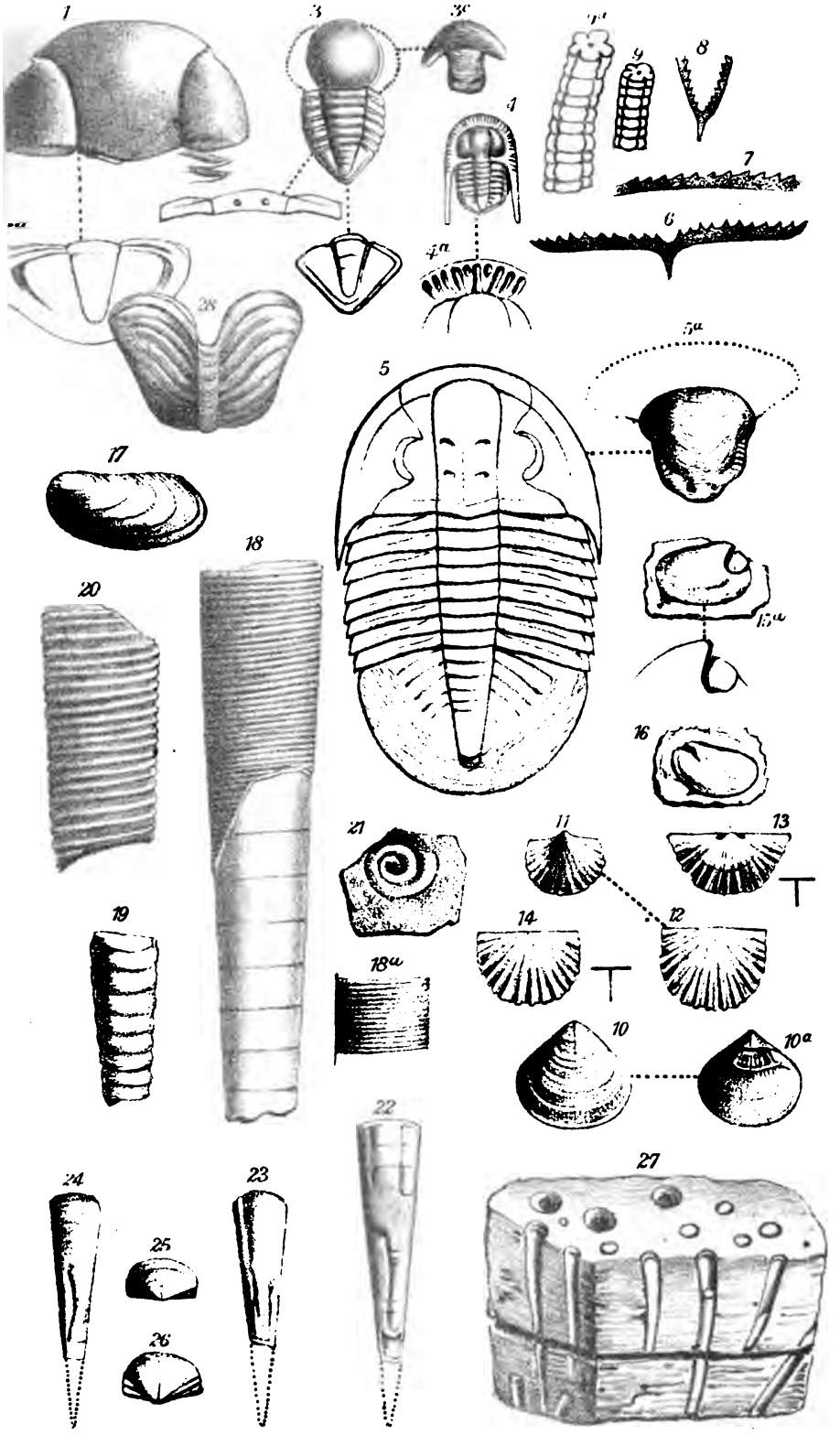
PLATE 11B.

LOWER LLANDEILO.

Illænus; figs. 1, 2.
Æglina binodosa, Salter; fig. 3.
Trinucleus Murchisoni, Salter; fig. 4.
Ogygia Selwynii, Salter; fig. 5.
Didymograptus; figs. 6–8.
Cyathocrinus; fig. 9.
Lingula plumbea, Salter; fig. 10.
Orthis, two species; figs. 11–14.
Cucullela anglica, Salter; fig. 15.
Ribieria complanata, Salter; fig. 16.
Palæarca amygdalus, Salter; fig. 17.
Orthoceras, two species; figs. 18–20.
Ophileta; fig. 21.
Theca simplex; figs. 22–26.
Worm burrows (Scolithus); fig. 27.

ological Survey of the United Kingdom. (ARENIG)



M Dingwall lith.

PLATE 12.

LOWER LLANDEILO.

Diplograptus, two species; figs. 1, 1A.
Annelide burrows; fig. 2.
Calymene parvifrons; fig. 3.
Asaphus affinis, M'Coy; fig. 4.
Orthis calligramma, Dalm.; fig. 5.
Obolella; figs. 6, 7.
Ogygia peltata, Salter; fig. 8.
Trinucleus, two species; figs. 9, 10.
Æglina, two species; figs. 11, 12.

Geological Survey of the United Kingdom.

PLATE 12
(ARENIG)

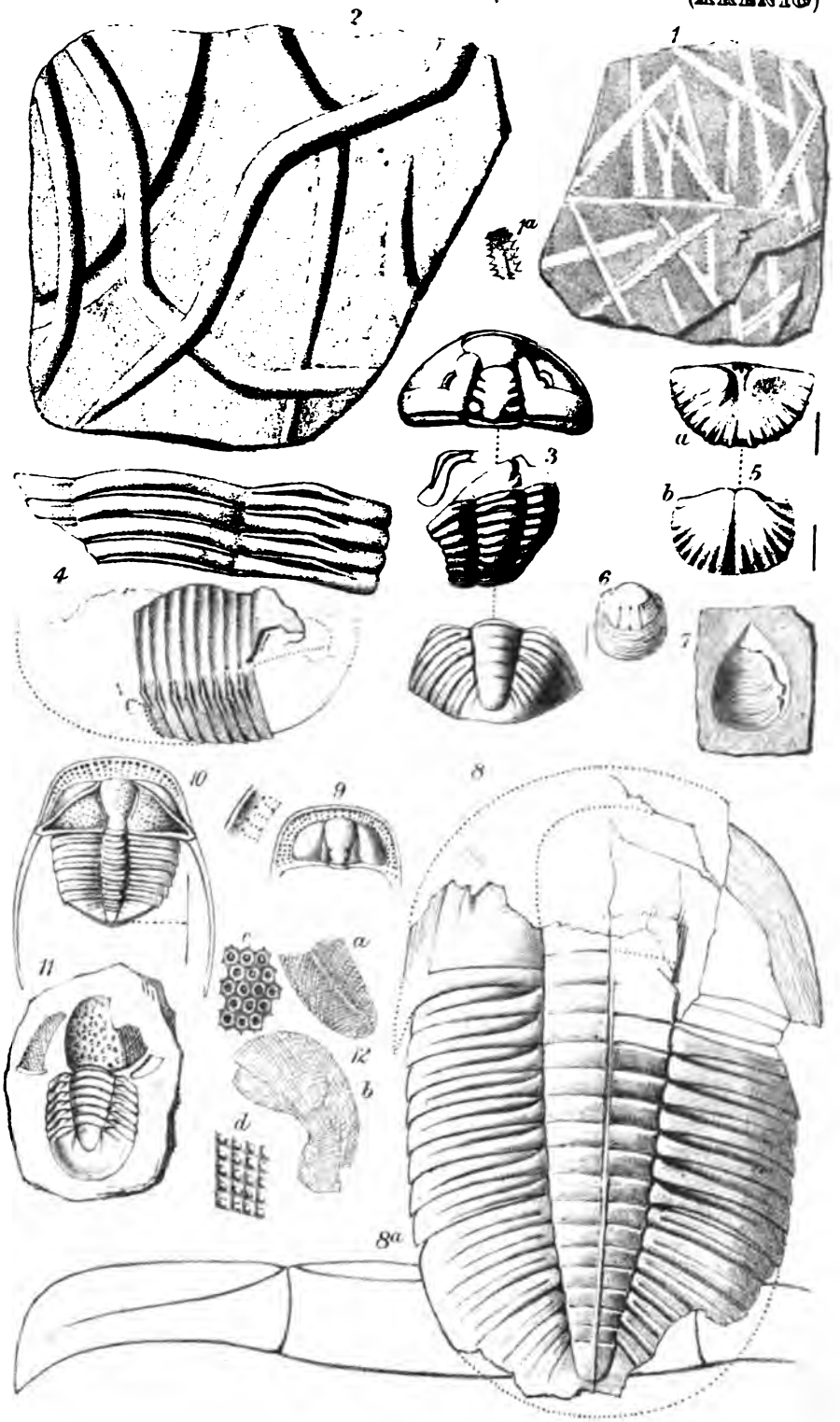


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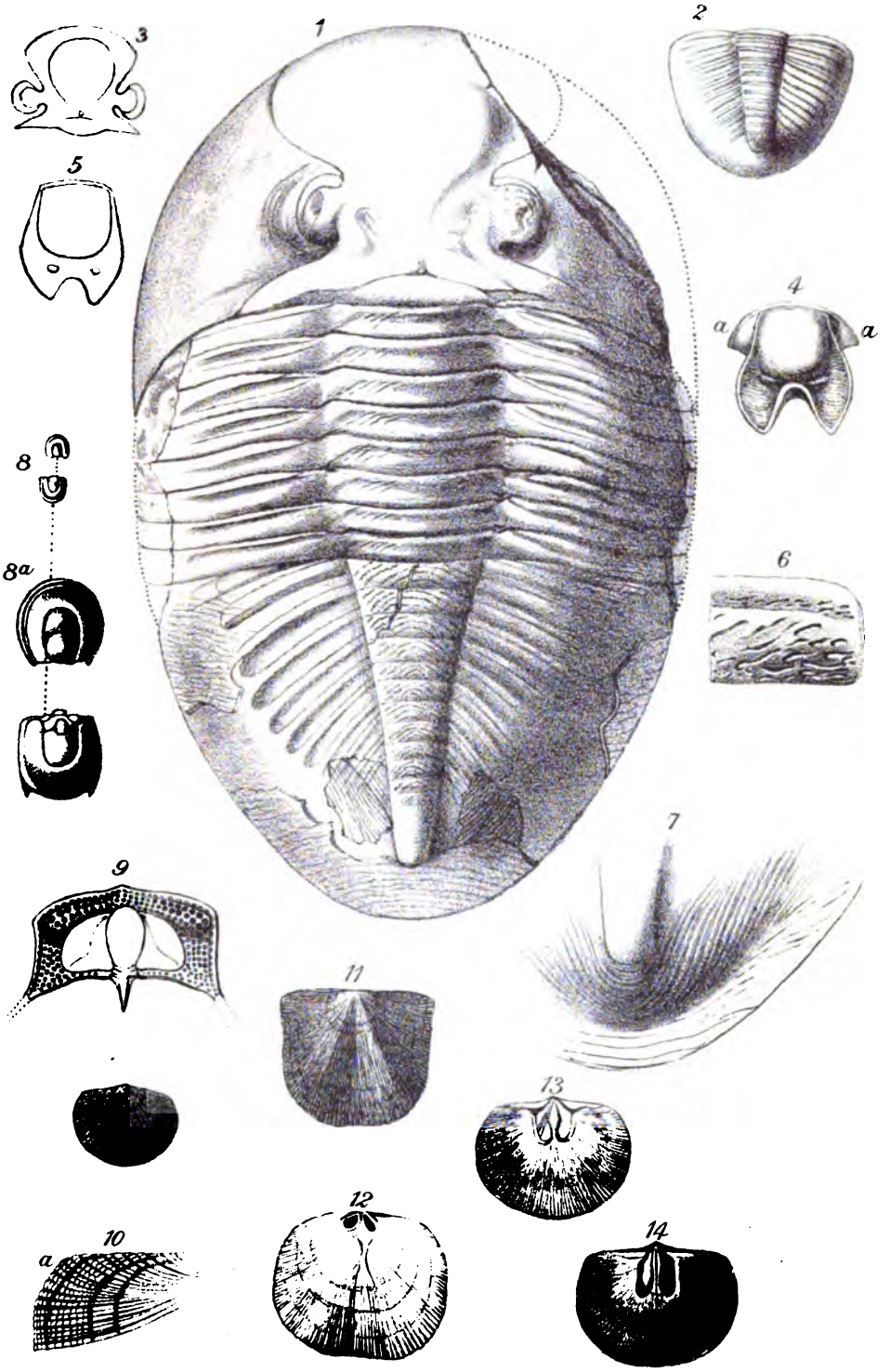
PLATE 13.

LLANDEILO FLAGS.

Asaphus tyrannus, Murch.; figs. 1–7.
Agnostus M'Coyii; fig. 8.
Trinucleus favus, Salter; fig. 9.
Orthis striatula, Conrad; figs. 10–14.



F Dan.

PLATE 14.

Caradoc, or Bala.

Annelide tubes; figs. 1–4.
Fucoids; figs. 5, 6.

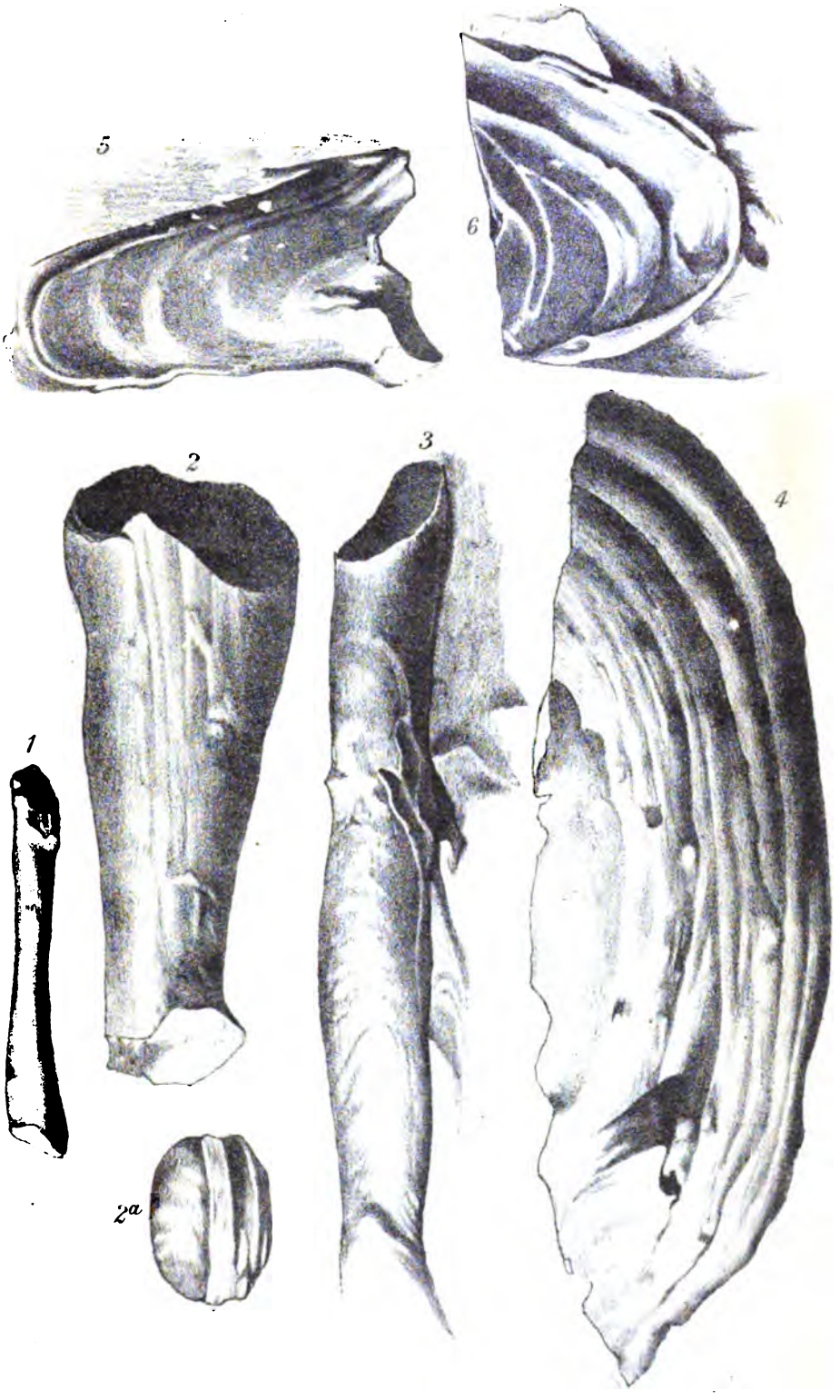


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PLATE 15.

CARADOC, OR BALA.

Asaphus Powisii, Murch.

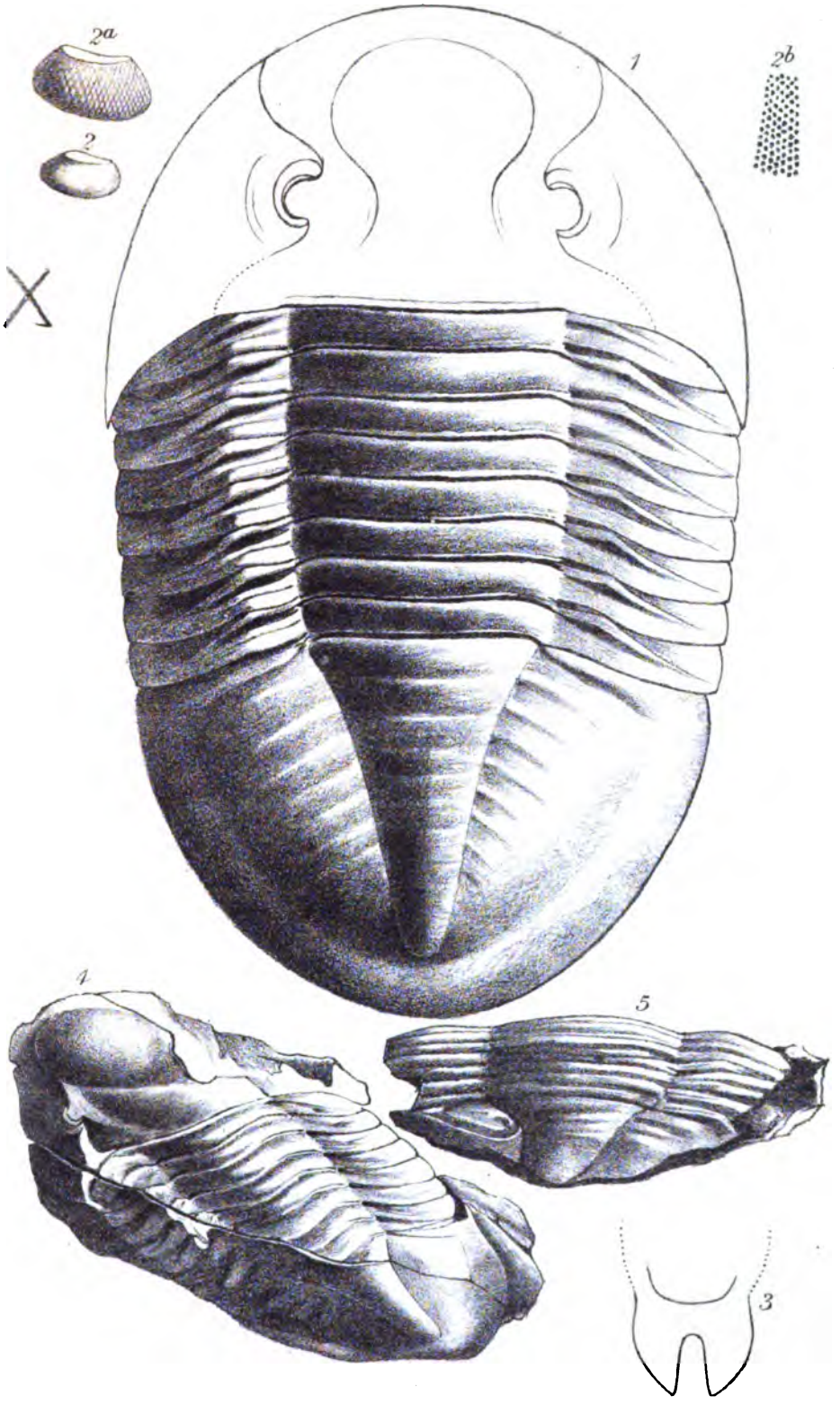

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PLATE 16.

CARADOC, OR BALA.

Homalonotus bisulcatus, Salter; figs. 1–8.
„ rudis, Salter; figs. 9–11.

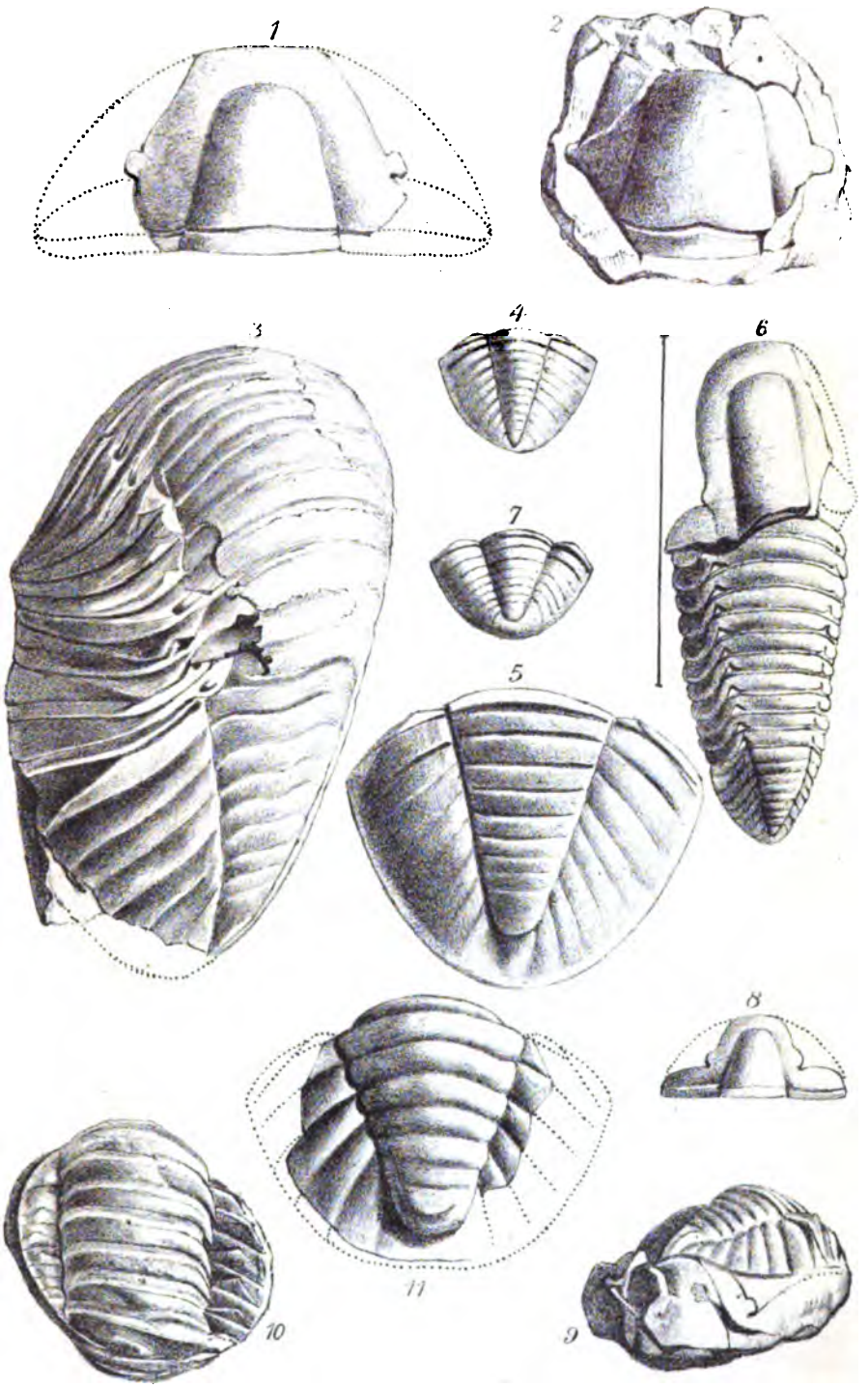

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PLATE 17.

CARADOC, OR BALA.

Calymene Blumenbachii, Brong.; figs. 1–7.
,, var. brevicapitata, Portlock; figs. 8–12.
,, Cambrensis, Salter; figs. 13, 14.
,, duplicata, Murch.; figs. 15–20.

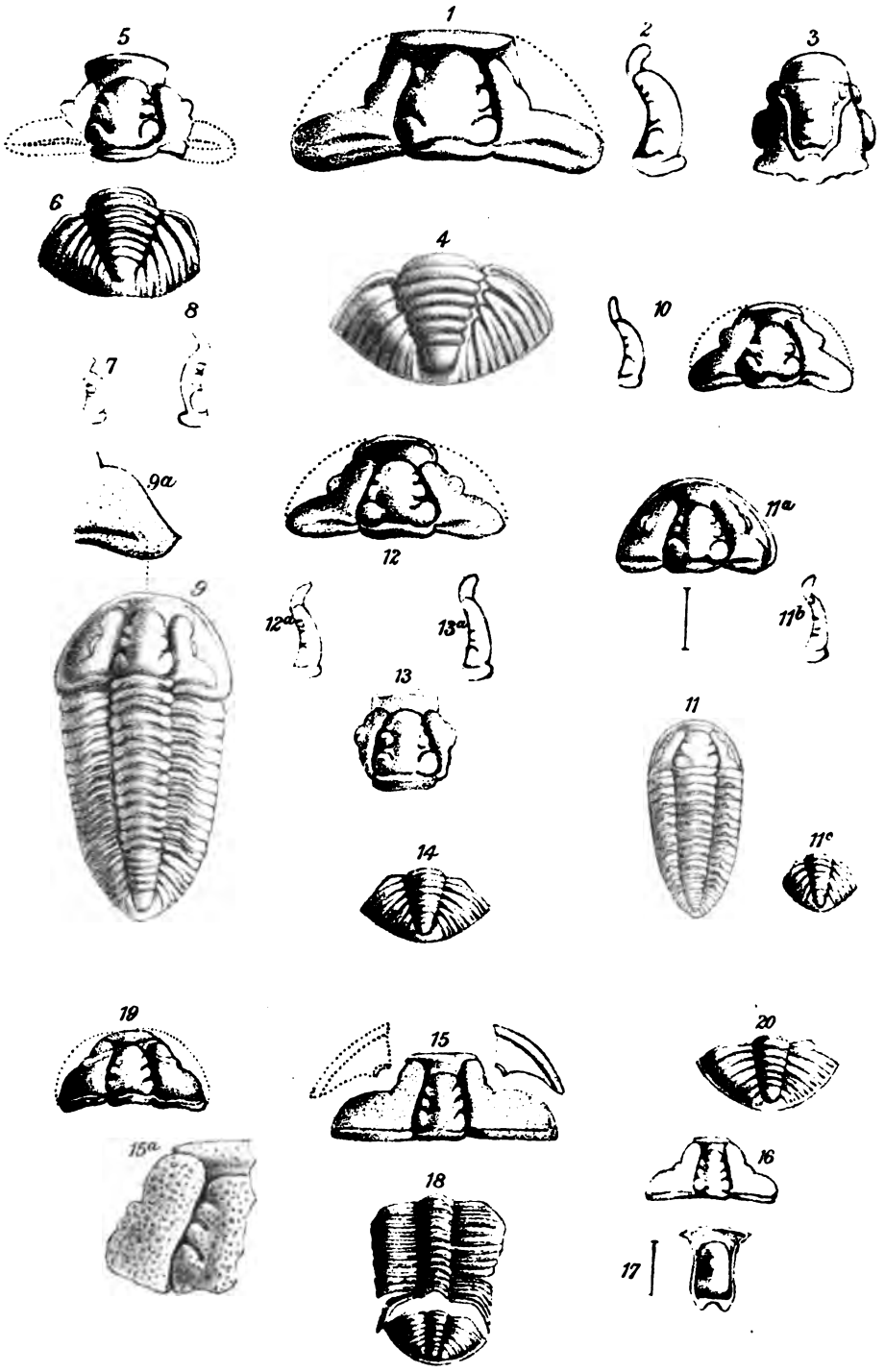

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PLATE 18.

CARADOC, OR BALA.

Cheirurus juvenis, Salter; figs. 1, 2.
„ octolobatus, M'Coy; fig. 3.
„ bimucronatus, Murch.; figs. 4, 5, 6, 7.
Illænus Bowmanni, Salter; fig. 8.
——— Davisii, Salter; fig. 9.

Geological Survey of the United Kingdom.

PLATE 18
(CARADOC OR BALA)

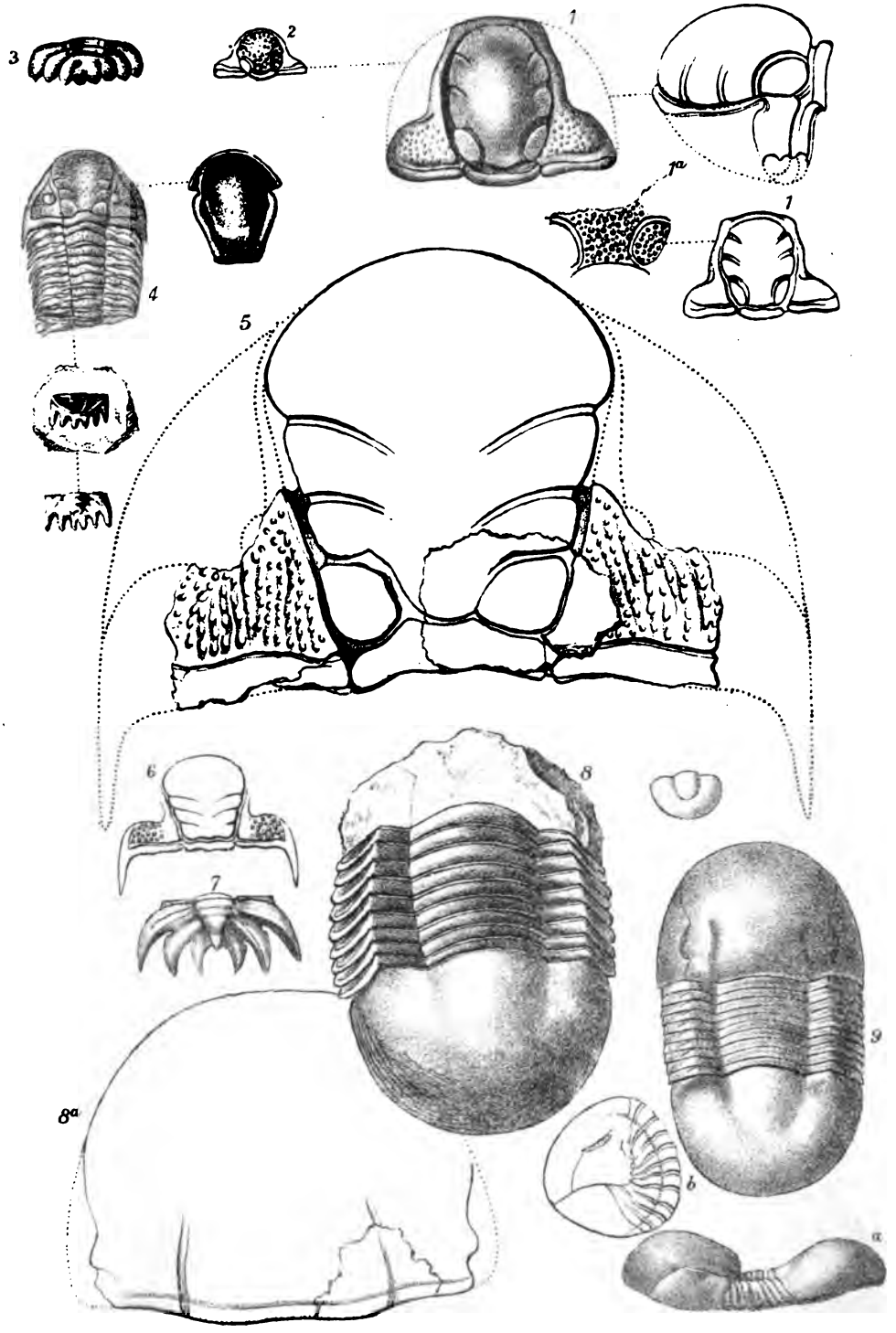

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PLATE 19.

CARADOC, OR BALA.

Lichas laxatus, M'Coy; figs. 1–3.
Trinucleus concentricus, Eaton; fig. 4.
Encrinurus sexcostatus, Salter; figs. 5, 6.
Cybele verrucosa, Dalm.; fig. 7, head.
Agnostus trinodus, Salter; fig. 8.
Beyrichia complicata, Salter; fig. 9.
Nebulipora favulosa, Phill.; fig. 10.
Orthis alternata, Sby.; figs. 11–13.
,, porcata, M'Coy, var. retrorsa; fig. 14.

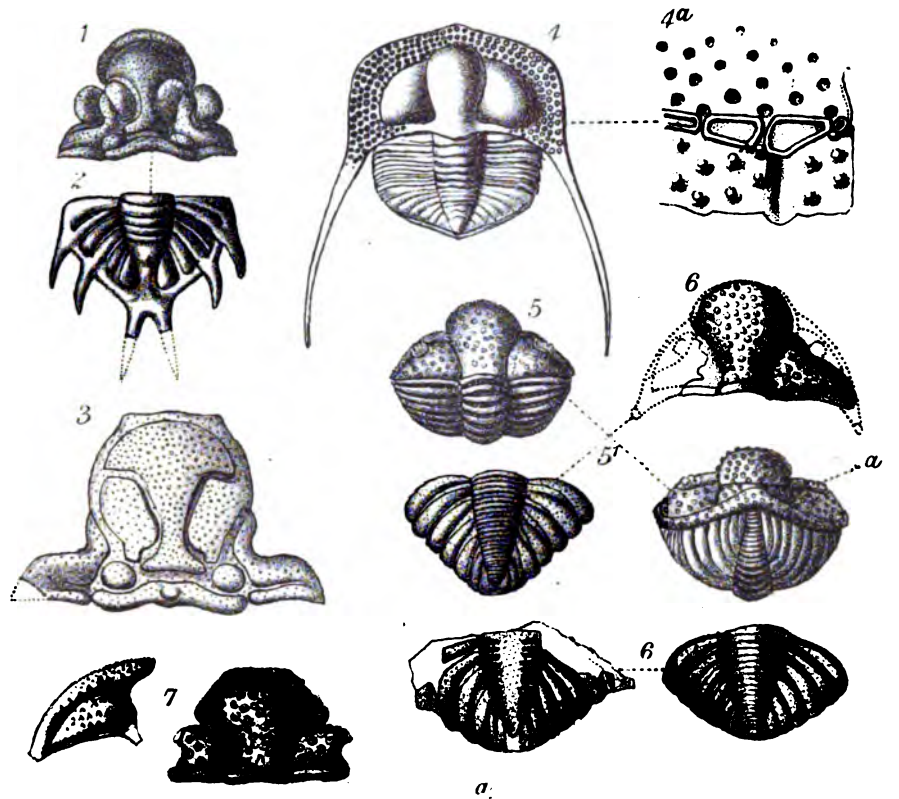

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PLATE 20.

CARADOC, OR BALA.

Sphæronites pyriformis, Forbes; figs. 1, 2.
,, munitus, Forbes; fig. 3.
,, Litchi, Forbes; fig. 4.
Pleurocystites Rugeri, Salter; fig. 5.
Sphæronites stelluliferus, Salter; fig. 6.
,, punctatus, Forbes; fig. 7.
Echinosphærites Arachnoideus; fig. 8.
,, Davisii, M'Coy; fig. 9.
,, Balthicus, Eichw.; fig. 10.
Hemicosmites oblongus, Pander; fig. 11.
,, rugatus, Forbes; fig. 12.
Agelacrinites Buchianus, Forbes; fig. 13.

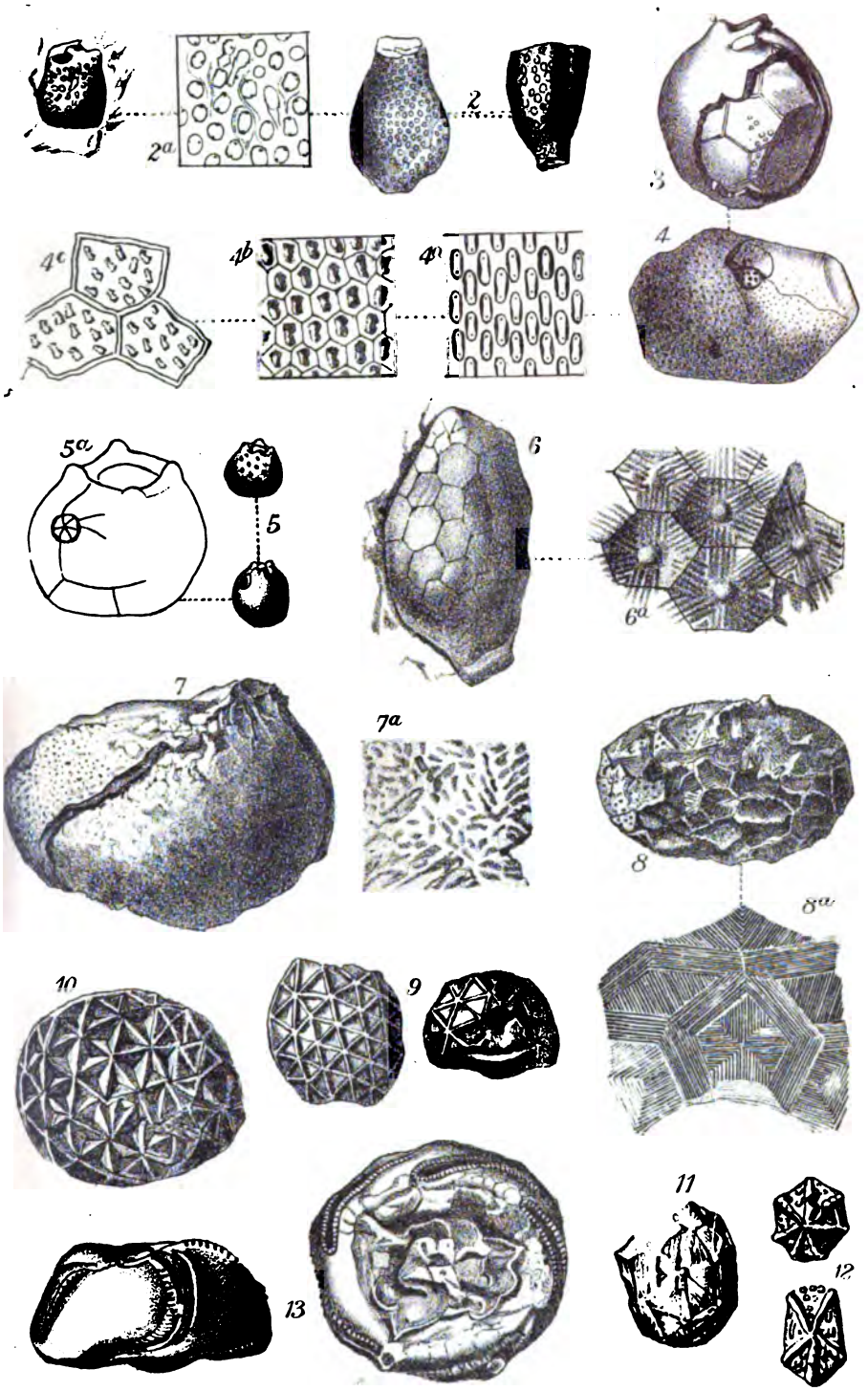

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PLATE 21.

CARADOC, OR BALA.

Orthis actoniæ, Sow.; figs. 1–8.
„ flabellulum, Sow.; figs. 9, 16.

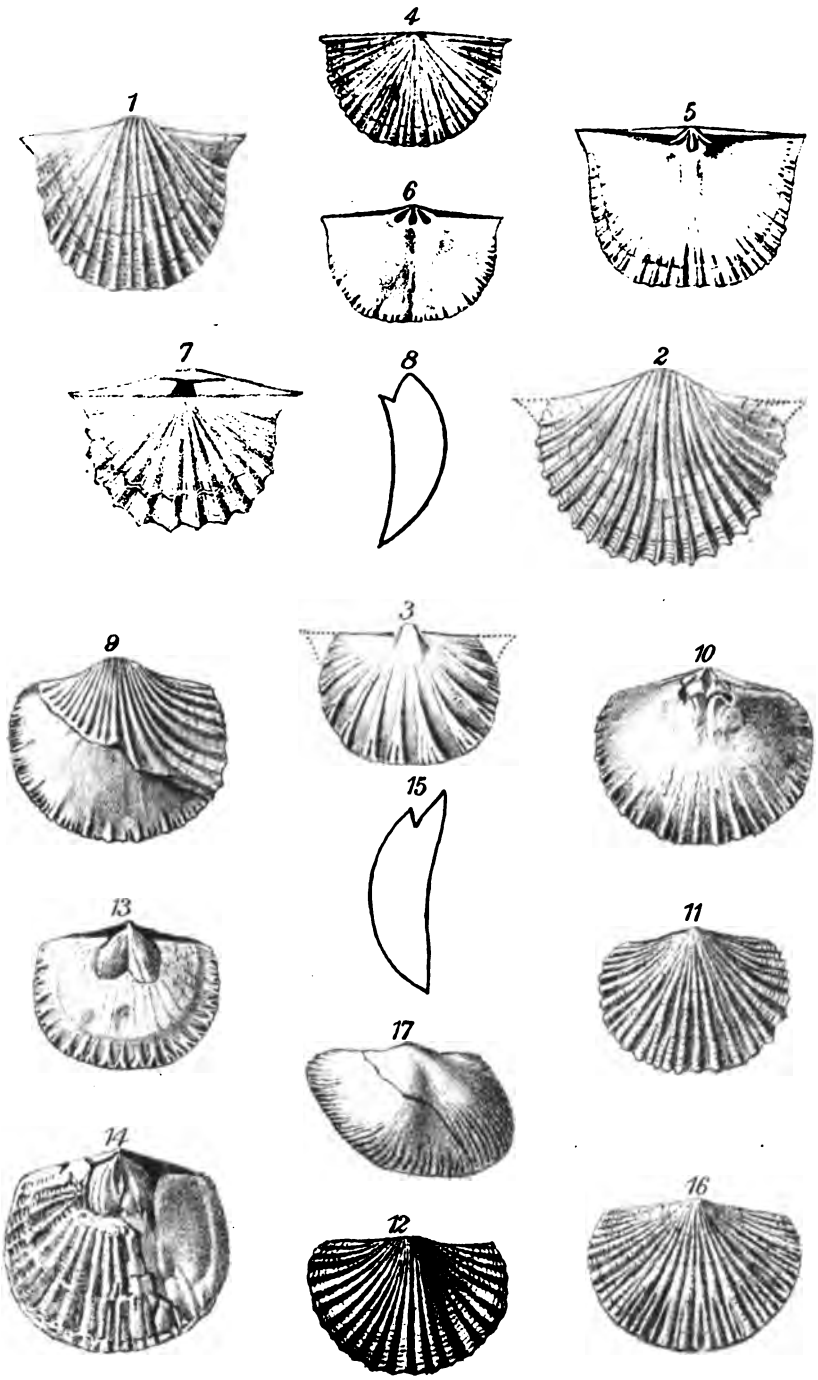

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PLATE 22.

CARADOC, OR BALA.

Orthis calligramma, Dalm.; var. proava; fig. 1.
,, ,, var. Calliptycha, M'Coy; fig. 1.
,, ,, ,, virgata, Sow.; fig. 2.
,, ,, ,, simplex, M'Coy; fig. 4.
,, ,, ,, plicata, Sow.; fig. 5.
,, ,, ,, Wallsallensis, Dav.; figs. 6, 7.

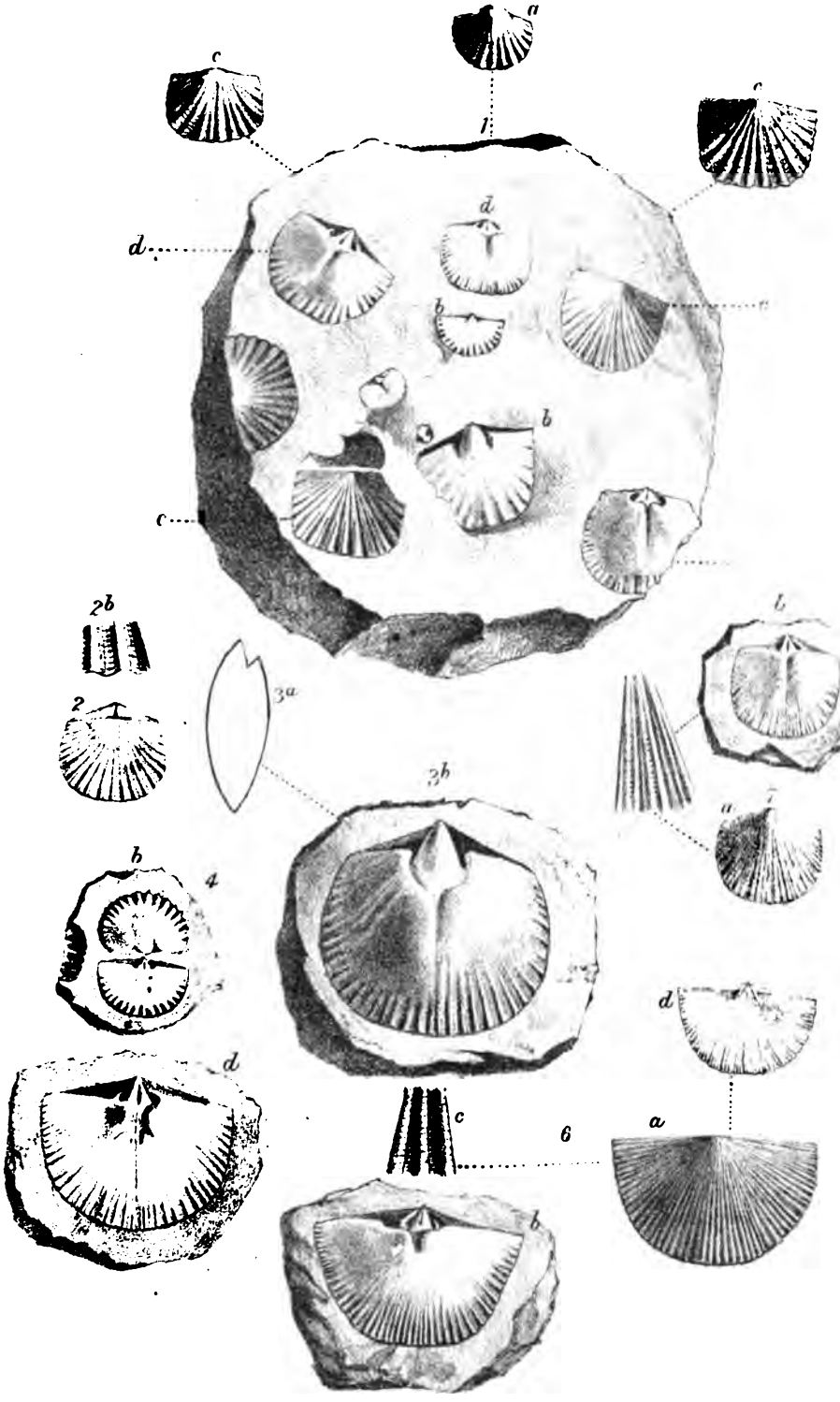

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PLATE 23.

CARADOC, OR BALA.

Palæaster obtusus, Forbes; fig. 1.
,, asperrimus, Salter; fig. 2.
Protaster Salteri, Forbes; fig. 3.
Glyptocrinus ? basalis, M'Coy; fig. 4.
Pleurocystites Rugeri, Salter; fig. 5.
Ampyx tumidus, Forbes; fig. 6.
Asaphus radiatus, Salter; fig. 7.
Palæaster imbricatus, Salter; fig. 8.

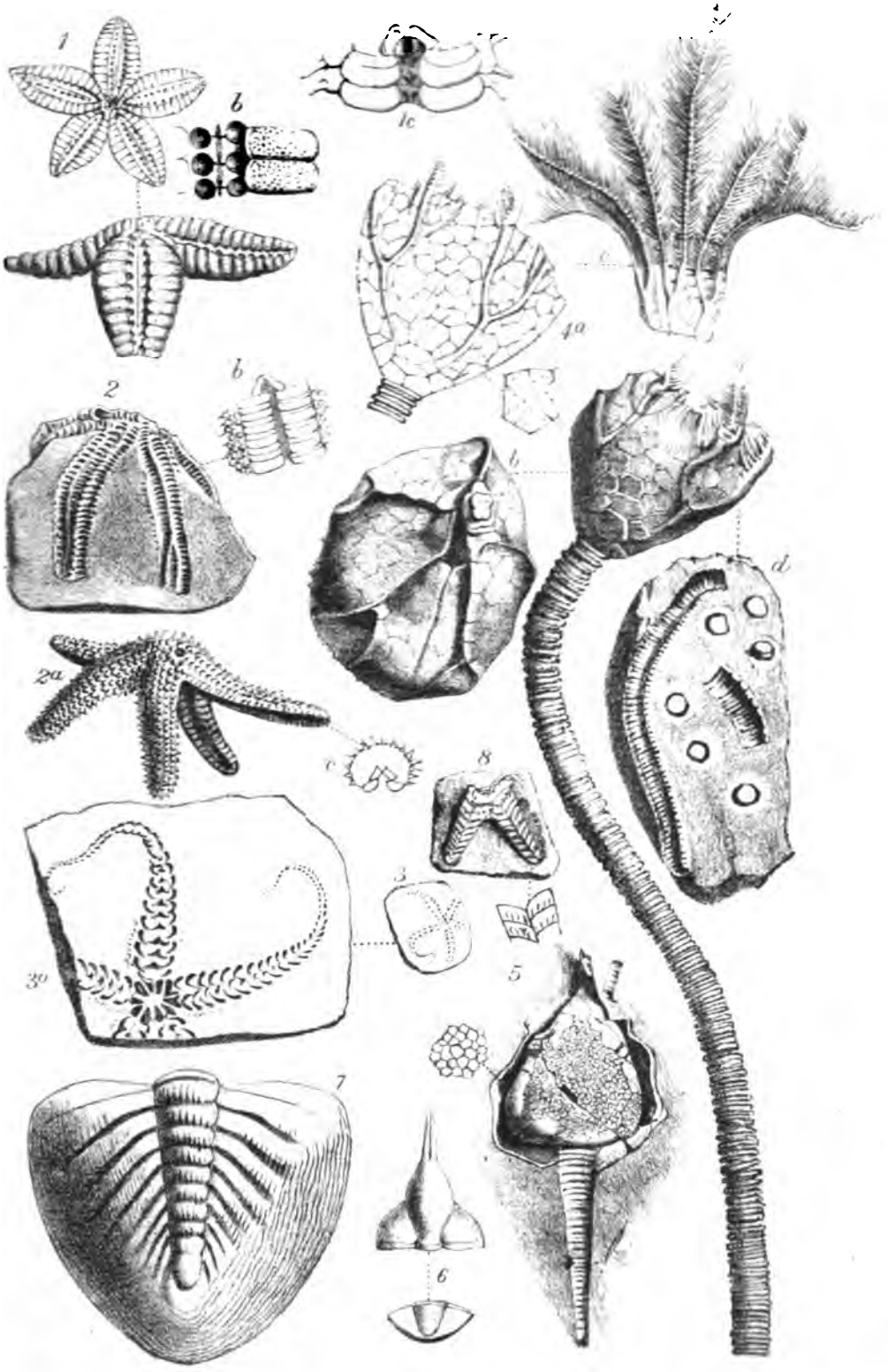

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PLATE 24.

CARADOC, OR BALA.

Orthoceras vagans, Salter; figs. 1–5.
,, sp.; fig. 6.
,, audax; fig. 7.

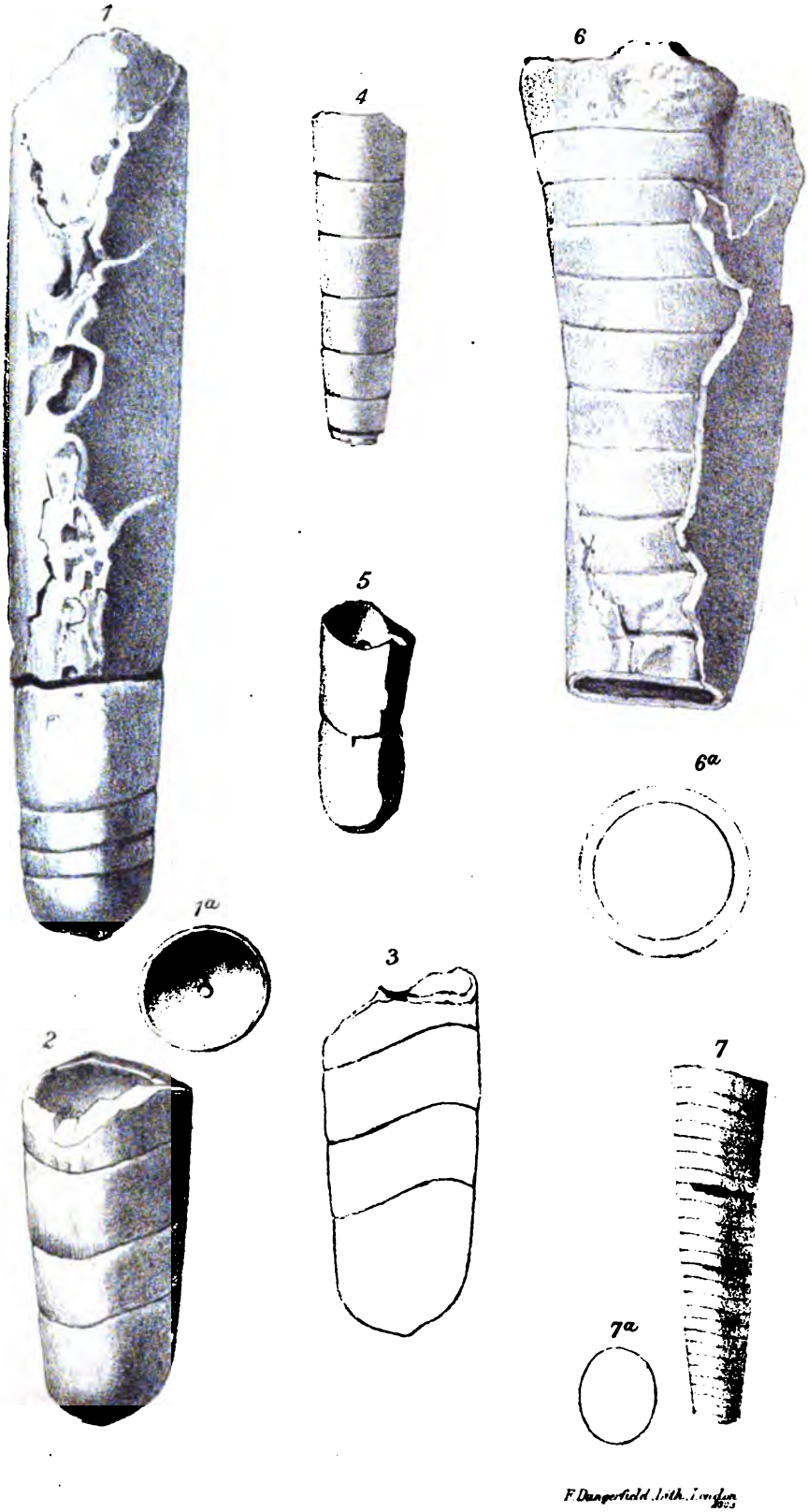

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PLATE 25.

CARADOC, OR BALA.

Cyrtoceras sonax, Salter; fig. 1.
,, atramentarium, Salter; figs. 2, 3, 4.
Lituites (Trocholites) planorbiformis, Conrad; fig. 5.

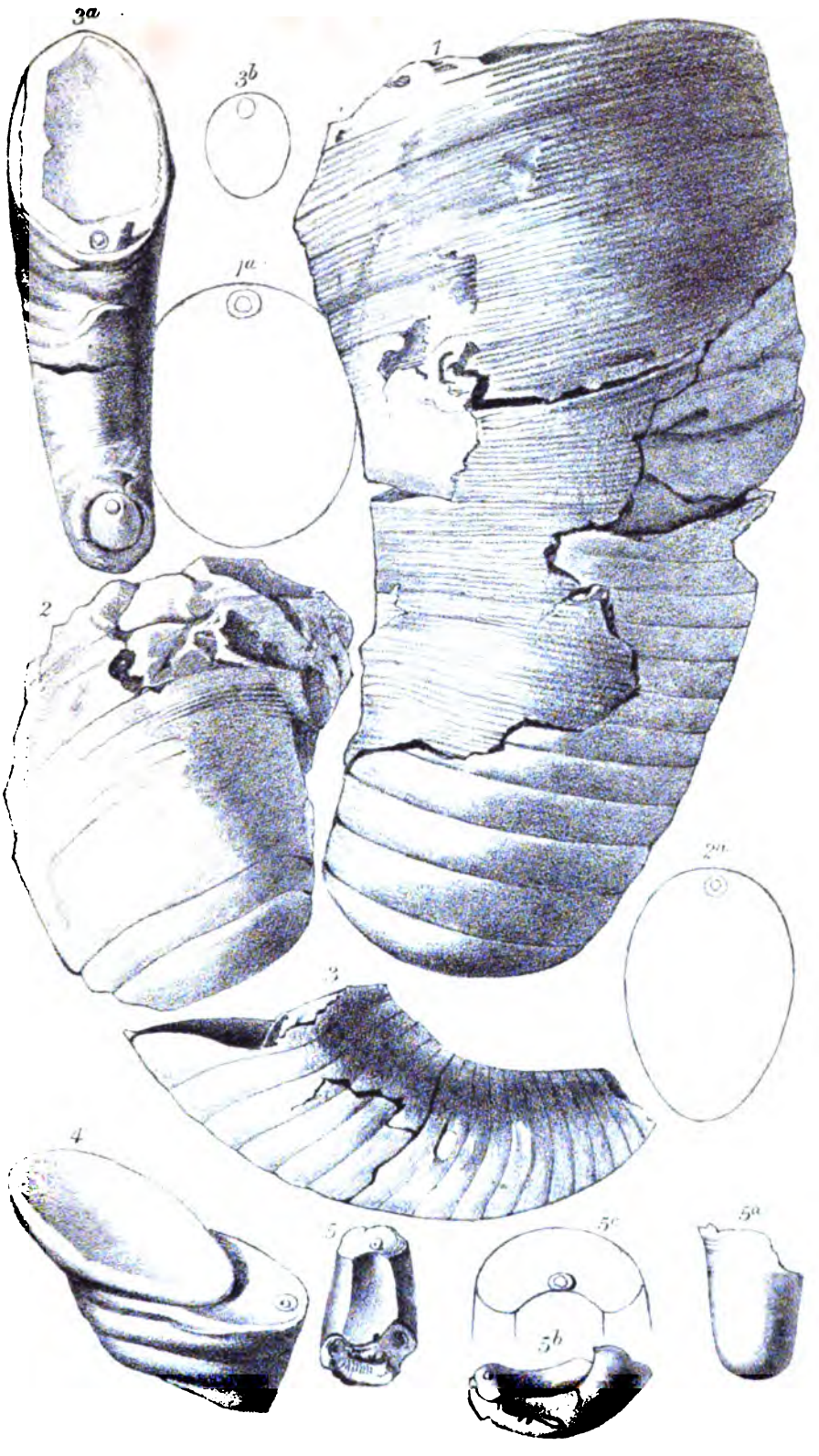

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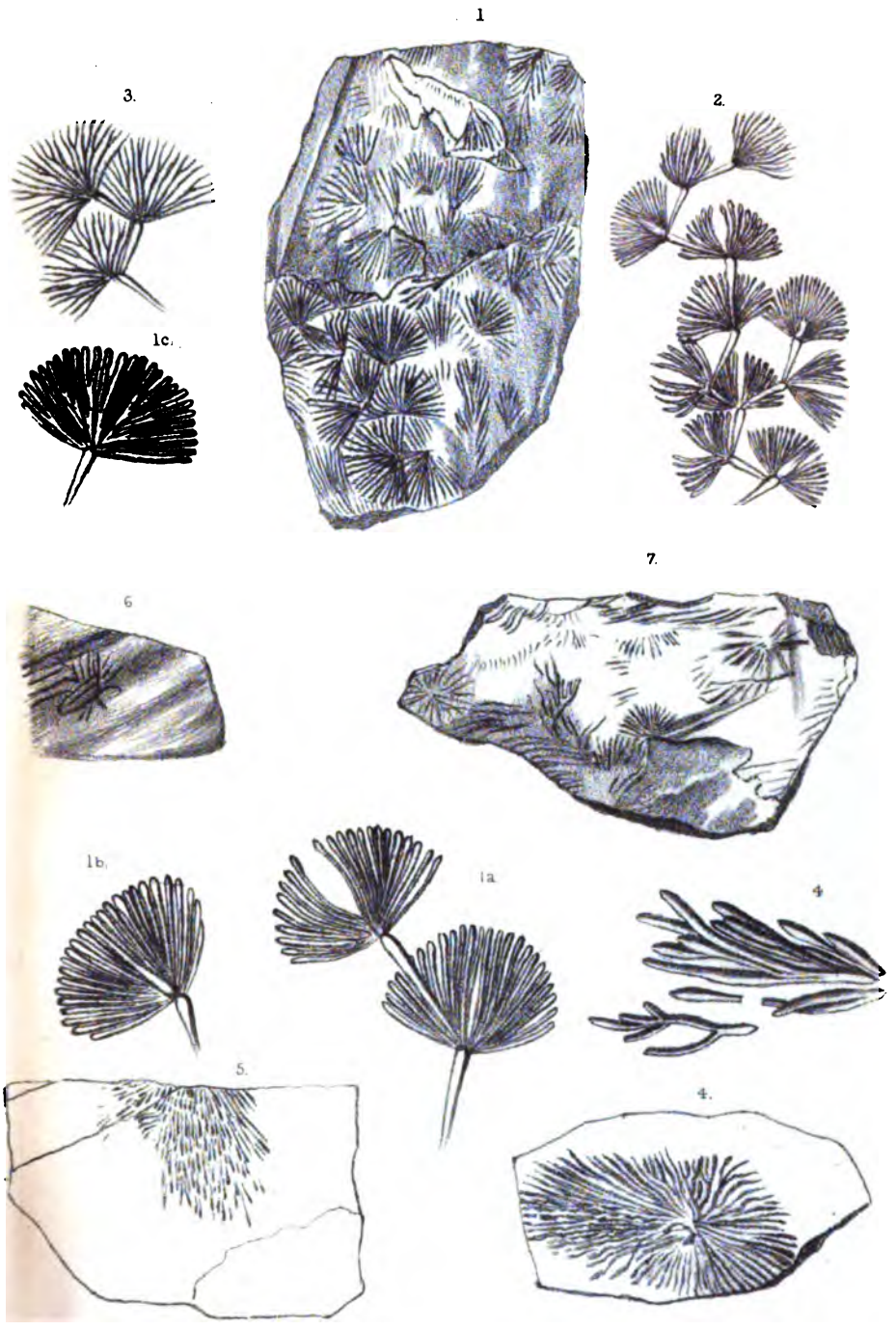
PLATE 26.

CAMBRIAN.

Oldhamia antiqua, Forbes; figs. 1, 2, 3.
„ radiata, Forbes; figs. 4, 5.
„ „ var.; figs. 6, 7.



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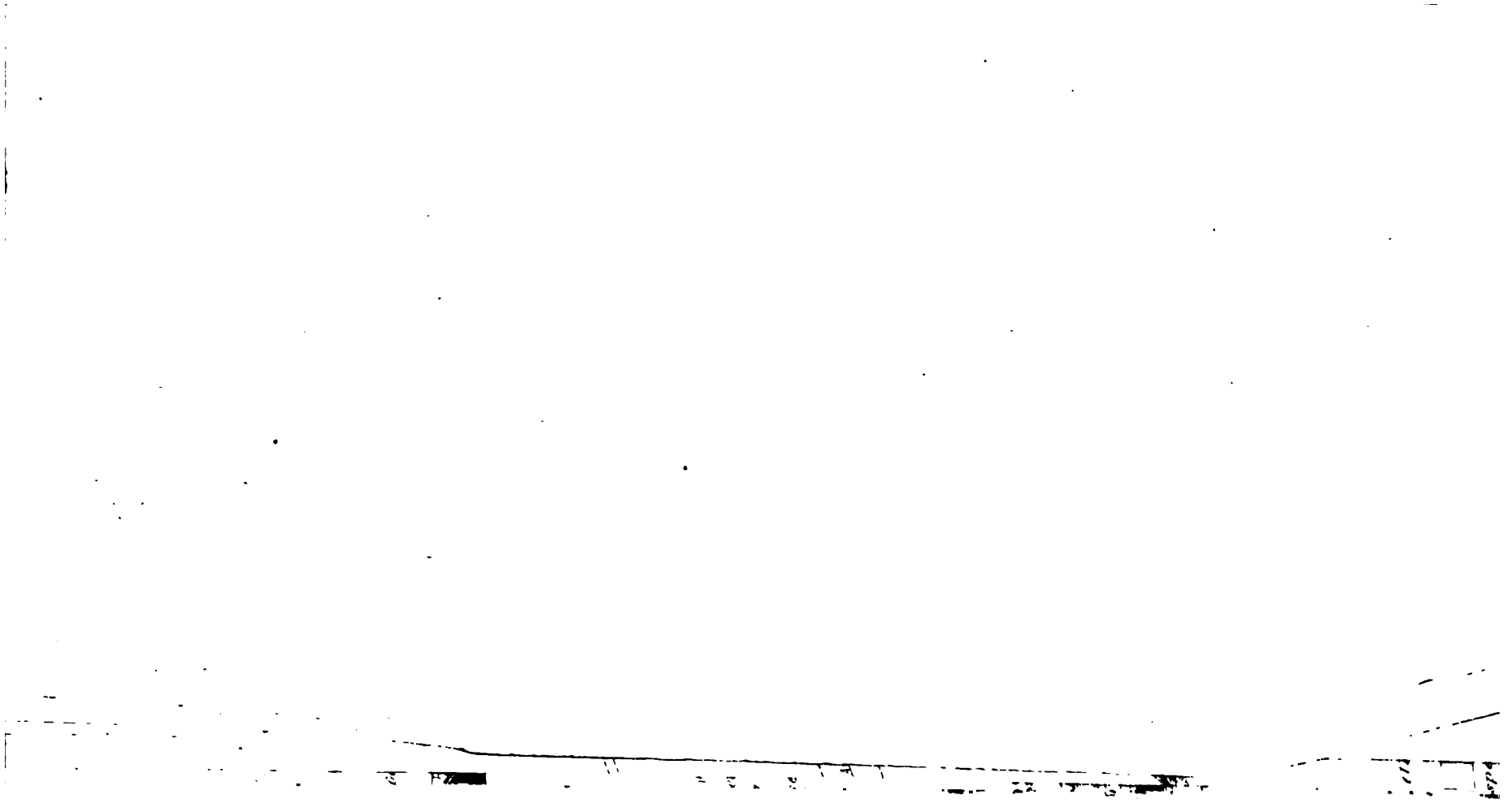

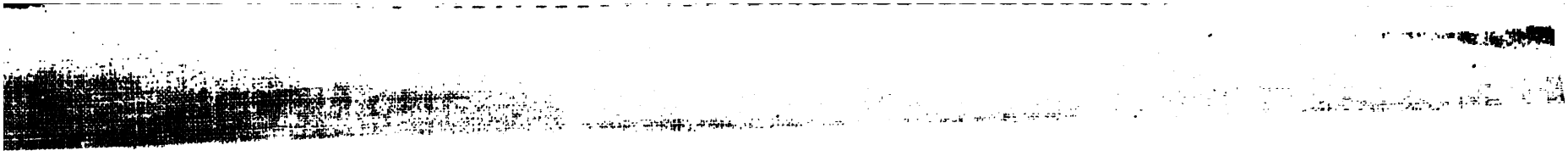

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